ASTRONOMICAL ESSAYS

GEORGE V. LEAHY

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BY THE

REV. GEORGE V. LEAHY, S. T. L.

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IS

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TO THE

MOST REV. WILLIAM H. O'CONNELL, D.D.,

ARCHBISHOP OF BOSTON,

UNDER WHOSE

KINDLY AUSPICES AND ENCOURAGEMENT

IT WAS

INITIATED AND BROUGHT TO COMPLETION

"Why did not somebody teach me the constellations, and make me at home in the starry heavens, which are always overhead, and which I don't half know even to this day?"

THOMAS CARLYLE.

FOREWORD.

This volume of astronomical essays has been compiled from a series of articles originally published in the *Boston Pilot* over the pen-name of Catholicus. The series is here presented connectedly at the request of the Most Reverend Archbishop of Boston, who has graciously written the author, "I highly commend your articles on astronomy for publication in book form."

A new book on the science of the heavens needs no apology. There will always be found many, like Carlyle, eager to learn more and more concerning the occupants of the sky. Even to persons only moderately interested in nature, must occur from time to time certain pertinent questions. Some will be curious to learn of the distance of the heavenly bodies. How far from us are those gleaming lights? Are they our near neighbors, as they appear to be, or are they, on the contrary, many miles away? Again, what of their size? Are they but shining disks and points, or are they perhaps globes comparable to our great earth? Others will ask of their physical condition, whether it is like or unlike that of the earth? What is the purpose of their being? And, above all, do they show signs of possessing living occupants? These, and kindred questions, will find an answer in the following chapters, especial emphasis being given to the important subject of the habitability of the heavenly bodies.

As will be observed, the series begins with a chapter on the shape of the earth. Some, reading the chapter,

may experience surprise that so much space has been allotted to a subject so simple and familiar. The topic has, however, been expanded advisedly, not only because it forms the starting-point of all astronomical inquiry, but because the fact of the earth's spherical shape is the initial wonder of the universe. Once we have realized that this great earth of ours is a globe set apart in space and suspended in mid-ether without support, with all that this signifies, we are prepared to accept the later affirmations that the earth is spinning on an axis and coursing through space about the sun. These and other cardinal truths of astronomy have undoubtedly long since become familiar. If the arguments in their favor are here set forth at considerable length, it is that the reader may know how firm are the foundations on which the science ot astronomy rests.

Besides the purely scientific chapters, drawn from systematic astronomy, there are others of a more apologetic trend. Their general purpose is to prove that neither the Christian religion nor the Catholic Church is in any way opposed to the science of astronomy or to its progress. In this vein are the chapters on the Astronomy of the Bible, that of the Fathers, and that of the Middle Ages, subjects not often treated, and seldom, if ever, gathered into the same volume. The modern era is even richer in material of apologetic interest. That Catholics have done their full share for the advancement of astronomy is set beyond doubt in the chapters on Copernicus, the Reform of the Calendar, and Recent Catholic Astronomers.

The most important portions of the book are those

that deal with the Case of Galileo and the Nebular Hypothesis. Not only popularly, but apologetically, these topics are among all that have been selected the chief in interest. They are rocks of offense on which the faith of many has suffered shipwreck. Special care has therefore been given to the handling of these two themes. The effect of the presentation will be, it is hoped, to remove misconceptions, to confirm the strong in faith, and to reassure the wavering.

Text-books on astronomy already abound. No better could be recommended to the interested reader than Newcomb's short Elements of Astronomy, published by the American Book Company. With this work and others of like character the present volume does not presume to enter into competition. It is meant rather as a book for general reading, for use in the library of one's home rather than for the school-room. Even as such, it has its limitations, of which the author is only too keenly conscious. He bespeaks it favor, nevertheless, because of the purpose it is intended to serve, the honor of God through the reverent study of the works of His creation.

The author wishes to acknowledge gratefully his indebtedness to Mr. James P. Sherry, a student at the Boston Seminary, for the chapter on Galileo as a Physicist.

Feast of the Resurrection, 1910.

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PRAISE OF THE CREATOR.

"The spacious firmament on high,
With all the blue ethereal sky,
And spangled heavens, a shining frame,
Their great Original proclaim. . . .

"What though, in solemn silence, all
Move round this dark terrestrial ball;
What though no real voice nor sound
Amid their radiant orbs be found;
In Reason's ear they all rejoice,
And utter forth a glorious voice,
For ever singing as they shine,
'The hand that made us is divine.' "

JOSEPH ADDISON.

ASTRONOMICAL ESSAYS.

CHAPTER I.

THE SHAPE OF THE EARTH.

Some people find it strange that a study of the earth should be included in the science of astronomy. Is not astronomy, they ask, the science of the stars and heavenly bodies? Now, they argue, the earth is not one of the heavenly bodies; it is not located in the sky, it is right here under our feet. How, then, and by what twisting of words can it be given a place in astronomy?

And yet this globe of ours has its place in the science of the heavens and, indeed, a place of real importance. It would be anticipating too much to say thus early that our earth is a planet, like Venus and Jupiter and certain other bodies that are visible in the firmament. Before we are ready to accept this statement, much argument and proof will be needed. Told us in the beginning of our investigation, it is merely a vain assertion. But even from now and at the very inception of our studies, we can realize that the earth is the vantage-point from which alone it is given us to examine the myriads of lights that dot the heavens.

The Earth Our Observatory. All our inspection of the celestial bodies, all our measurement and analysis of them, must start from the earth as our viewpoint and centre. It is truly our astronomical observatory, from which alone we can measure the sizes, angles, and distances of the objects that people the heavens. Hence, before we can learn anything definite about the sun, the moon, and the stars, we have to understand our own earth and, above all, we need an accurate knowledge of its shape and size. If we start with a wrong conception of these, we shall be betrayed into innumerable errors regarding all astral bodies. This is the justification for beginning the present series of astronomical sketches with a chapter on the true shape of the earth.

Belief of the Ancients. All primitive peoples thought of the earth's surface as a flat, level plain, roughened, it is true, by hills and mountains and indented by valleys and ravines, but still in its larger aspects a level, horizontal expanse of land and sea. Indeed, is not this its obvious appearance? From any single post of observation, even if it be a mountain-top or the ocean with its unimpeded view, who would doubt that the earth is level, who would infer that it slopes away in the form of a curve? Even today there are some persons,—and we need not go beyond Boston to find them,—who still proclaim their belief in the flatness of the earth. We may charge them with being crassly ignorant. But how should we set about to refute them? The simple testimony of the senses seems to say that the earth is level. I may ride for a thousand miles in a railroad train from Boston to

Chicago and except for the slight upgrades and downgrades due to intervening mountain slopes, I shall certainly think that I have been following a dead level line. Or I may cross the Atlantic in an ocean liner and in that long journey of three thousand miles never once realize that I am being borne around the surface of a sphere. Whether on land or sea, the earth seems a plain, and if I trust only to first appearances, I shall pronounce it such.

It must not surprise us, then, to learn that of old all men, even the wisest, conceived the earth's surface as a level plain. In the olden times, in the morning of the history of the race, people did not travel as readily as now; they had no cars or boats propelled by steam or electricity to whirl them from one place to another. They had for means of travel only their limbs, and beasts of burden like the camel and the horse. To voyage a hundred miles was for them a serious journey. They sojourned but little in foreign lands and among strange peoples, and in turn few strangers came among them. And when strangers did arrive from the distance of a few hundred miles they were said to have come from afar.

Geography of the Jews. How small, for example, was the portion of the earth's surface known to the early Hebrews! Their knowledge of geography was limited to the southwestern corner of Asia and the northeastern corner of Africa. Besides Palestine, the land of the promise, they knew of countries to the north verging towards the present Black Sea, of Egypt and Arabia to the south, and of Mesopotamia to the east. How narrow the boundaries that encompassed the then known earth! The Black Sea, the Mediter-

ranean, the Nile River, a line stretched across Arabia from the upper Red Sea, and the Euphrates River to the east, these formed very nearly the uttermost boundaries of the earth as it was known to the ancient Jews. In this space were included only three bodies of water of considerable size, the Red Sea, the Dead Sea, and the Mediterranean, and of the latter they had explored only the eastern end.

With such limited knowledge (for which, however, to blame them would be puerile), how natural it was that they should think of the earth's upper surface as perfectly level. How far it stretched they did not know, and said no man could know. But wherever it ended, it took the form of a vast horizontal circle, and on this circular rim was supported the great vault of the sky. Down under the earth's surface were subterranean basins for supplying the rivers and oceans, and lower yet were what they called the great abysses, of unfathomable depth.

Jews' Superiority of Concept. Undoubtedly all early peoples had some such notion of the earth's shape and structure as had the Hebrews. If the question occurred to them what it was that supported this immense earth and held it up, they answered variously according to their lights and fancies. Most primitive peoples, as even the lettered Hindus and the cultured Greeks, thought fantastically of some monstrous elephant or of some giant Atlas supporting the world upon his shoulders. To the credit of the Hebrews be it said that they avoided all such myths and childish fantasies, attributing the upholding of all things to the word of God's power (Heb. i, 3). It was God who had set up the pillars of the earth (Ps. lxxiv,

3). "He stretcheth the north over the empty place, and hangeth the earth upon nothing," such was the sublime and daring thought of the Book of Job (xxvi, 7), one of the many true and exalted concepts that lift the Hebrew Scriptures above the writings of every other primitive people.

PTOLEMY'S STUDY OF THE QUESTION.

The first man who proved clearly that the earth is a globe was Ptolemy, the illustrious Grecian astronomer of the second century of the Christian era. When we read his arguments, we see that, as far as they extend, they are just as convincing as are our proofs of today.

Ptolemy's First Argument. Consider, for example, his argument of the manner in which a ship disappears as it recedes from the shore. If it were riding on a level, it would disappear from sight all at once, at the moment when our power of sight was now too feeble to follow it. But, as a matter of fact, it sinks from sight as if it were being swallowed up in a trough. The hull of the vessel disappears first, declining below the water's edge, but for some time after we may still see the decks, the masts, and the sails. These then disappear in the order of their height, the topmast and its sails last of all. To all appearances the ship has been gradually submerged. But were we on the ship instead of on the shore, we should still find our craft riding the waves in safety.

The only possible explanation of the gradual disappearance of the vessel part by part, is that she has been following not a horizontal line but a line bent away from the horizontal in the form of a continuous

curve, and that in this instance at least the ocean's surface is not level but curvilinear. The observations of Ptolemy made at Alexandria in Egypt eighteen hundred years ago, can be easily repeated by us in Boston Harbor or Massachusetts Bay in the present year of grace and with the same results. Indeed they can be repeated on any and every ocean, sea, or large lake throughout the world. The earth, then, is nowhere flat as its first appearance indicates, but everywhere slopes away from a level in the form of a circular arc.

Argument from the Stars. Ptolemy's second argument, though not so simple, is however equally cogent. It rests on the change in our starry heavens as we alter our position on the earth to some different degree of latitude. As we move to the southward, for example, particularly if our journey covers many miles, new stars and constellations appear above our southern horizon and the old ones are displaced. From Boston we are never privileged to behold such brilliant constellations as the Centaur and the Southern Cross. But let us travel southward to the Tropic Zone, then these glittering groups of southern stars will rise above the margin of the sky.

It must be that our southern horizon has been depressed so low as no longer to act as a screen between us and them. Were the earth level, the horizon would hold its direction and position relative to us and these southern stars, and would continue to conceal them from our view. To the earlier readers of Ptolemy this argument meant more than it does to most of us. For in his time people made a practice of observing and studying the stars, and were quite familiar with their names and groupings. Among

the city-bred people of modern times there are very few who watch the stars and come to know their names and relative positions. The more's the pity, for they thus remain in ignorance of the details of that wonderful design which the Creator has imprinted on the heavens.

After Ptolemy. In view of the undoubted cogency of Ptolemy's twofold argument, how came it, we may ask, that in the Middle Ages so many doubted the sphericity of the earth, continuing to believe that its upper surface formed a level plain? Arguments from the Hebrew writings and a misunderstanding of their scope undoubtedly had some effect in counterbalancing the weight of Ptolemy's reasoning. There was moreover the apparently clear testimony of the senses that the earth is a flat body and not round. So throughout the medieval period some inclined to one belief and some to its opposite. It was a period of uncertainty as far as this particular problem was concerned, and the uncertainty was not finally dispelled till in the year 1521 the crew of Magellan, the Portuguese Catholic, accomplished the circumnavigation of the globe.

PRESENT LISTING OF THE ARGUMENTS.

In our present manuals of astronomy many separate lines of argument are traced, each going to show that the earth is of spherical form. Among these the four most striking may be summarily indicated as follows: First there is given Ptolemy's argument from the manner of a ship's disappearance at sea, as developed above.

Eclipses of the Moon. Secondly, eclipses of the moon afford a new ground for the inference that the earth's shape is spherical. Not infrequently, as a rule once or twice in every year, the full moon is eclipsed either wholly or in part by passing into the shadow of the earth. That it is the earth's shadow which causes the eclipse, there is not the slightest room for doubt. In every lunar eclipse then, we can witness the earth's shadow projected on the moon's surface just as truly as in other circumstances we can observe on the ground the shadow of a tree or building.

Now the shadow on the moon is always a circle or the segment of a circle, and this holds true for all eclipses no matter in what direction from the earth the moon be placed, whether over the eastern or the western hemisphere. From this it follows that the boundary of the earth is in its every part of circular form. For a shadow reproduces correctly the outline of the original as we plainly see in the case of a tree or building. We conclude, therefore, that if the earth's shadow is circular its boundary and contour must be circular also. And the only possible form of an object that will appear circular from whatever side it be viewed is the globular or spherical.

Analogy With the Heavenly Bodies. A third argument for the sphericity of the earth is that derived from analogy with the heavenly bodies. We know that the sun is a globe and that the moon is one as well. So, too, the planets, Mercury, Venus, Mars, and the rest, when viewed through a telescope, are seen to be quite evidently of spherical figure. Indeed the spherical is the usual and perhaps the universal form in inanimate nature, if the larger bodies alone

be considered. By analogy we should infer that our earth also is a globe. For in nature throughout its length and breadth all things follow common laws. Their unity of structure is indeed a proof of the unity of their Creator.

Circumnavigation of the Globe. Fourthly and finally, the earth is proved to be a sphere by the fact that it has been sailed around, first by the crew of Magellan, the Catholic, in the memorable voyage lasting from 1519 to 1521. Parenthetically it may be interesting to us of the United States to learn that this daring expedition of discovery was halted for a long time in the Philippine Islands and there, in a land now our colonial possession, Magellan himself, the commander, went to his death and lies buried. Many times since and in many different directions has the earth been circumnavigated, so that there is now abundance of observational proof as well as argument of mere reasoning to convince us that the earth is round.

Why Not Accepted Earlier? Once more may occur to us the wonder that the true shape of the earth was not earlier recognized. For it is now one of the most patent facts of science. But transporting ourselves back to the Middle Ages, we may easily realize how the above arguments failed of their effect. The fourth argument was not yet available. Till Columbus crossed the Atlantic, Europeans knew of no hemisphere other than their own. To the west and to the far east all was mystery. The first argument, that of Ptolemy, was well enough for determined localities. But who would assure the earlier people that the asserted phenomenon would hold good at every sea-

coast and every lake-border? It was an argument from induction and the induction was not yet sufficiently complete.

The argument derived from eclipses of the moon was probably never offered for their consideration, surely not with all its present force. Lunar eclipses were for them mysterious phenomena, attributed by some indeed to supernatural causes; and they would find it hard to believe that the shadow of the great earth could be so diminished as barely to cover the face of the moon. Finally the spherical figure of sun, moon and planets, even if fully assured to them, would scarcely suggest to their minds that the earth must have a corresponding form. For the heavenly bodies were placed by them in one category, the earth in another. The former were ethereal objects of strange substance moving lightly in the upper atmosphere; the earth was terrestrial, made not of fire but of land and water, God's footstool and the centre of the universe.

For all these reasons the world for centuries doubted or stood divided between two opposite opinions, one that of Ptolemy, founded on rational argument and asserting the rotundity of the earth, the other founded on sensible appearances and maintaining that at least the upper and habitable surface of the earth forms a level plain.

Conclusion. And now if a sceptic approaches you, young scholar, on Boston Common or elsewhere, and argues that the earth is not round like the globe in your schoolroom but flat like the maps in your geography, perhaps you will be able to refute him. Tell him of the ship disappearing part by part below

the horizon; tell him of the earth's circular shadow that covers the disk of the moon; point out to him the sun and moon and planets and let him say if these are not rounded bodies, and remind him of Magellan's trip around the globe. Submit to him finally that his error has been to mistake appearances for reality. "Things are seldom what they seem." Reason must ever be invoked to correct the misleading evidence of the senses. And in no department of knowledge will this correction be more often necessary than in the science of astronomy. For this in part has God given to man the noble faculty of reason. And it has been a part of God's providential plan, so proves the history of thought, to establish the worth of reason by guiding it gradually to a fuller knowledge of His visible creation.

CHAPTER II.

RELATIVE MAGNITUDE OF EARTH AND SUN.

In the panorama of the heavens as witnessed from the earth, the most impressive single object is undoubtedly the sun. Of all celestial bodies it is, or at least appears to us, the largest and the brightest. It makes our day and creates our seasons. When it shines, it dominates the heavens, putting to flight the other heavenly bodies almost without exception. In the starry realms it is the sun that seems to reign supreme. Supreme, therefore, must be its place in the science of astronomy. What sort of body is this brilliant orb, what is its distance from the earth and how great its size, these are evidently among the very first questions that astronomy must, if possible, answer.

In our present inquiry let us select for consideration the last-mentioned of these problems, that, namely, of the sun's volume or magnitude. Comparing sun with earth, let us seek to learn which is the larger body of the two, and whether they are almost alike or on the contrary far apart in size.

The Seeming Answer. At first view the answer to these queries seems ridiculously easy. For while the sun is evidently the mightiest of the heavenly bodies, when compared with the earth it seems to sink to a

place of insignificance. Is it not after all merely a light, brilliant and resplendent and dazzling, to be sure, but still a mere disk of light, so small that with our vision we can compass it all at once from end to end? Brightest of luminaries, yes, and yet so far from filling the sky that it would take hundreds of similar disks to cover the heavens even along one line.

MAGNITUDE OF THE EARTH.

And now behold under the sky this earth of ours, broad, expansive and seemingly unconfined, to all appearances as spacious in length and breadth as the firmament itself! With this wide earth, who thinks of comparing that narrow circle of light? It seems to me that could I seize that luminous ring and draw it down, I might find space for it on a certain round table in my dining hall.

Comparison Seems Absurd. Compare the sun's size and the earth's—someone is heard to say contemptuously—the very idea is preposterous. For do I not know that it takes days and days to travel from one coast of our continent to the other, even by the fastest express, and that to cross the succeeding ocean demands another week or even weeks? And do there not remain other continents to traverse broader than our own, and a second ocean to cross before home is reached again? Perhaps Jules Verne was not far from right in his guess when he chose as title for one of his fanciful stories, "Round the World in Eighty Days." Journey a little away from this favored city that we smugly call the Hub, and we shall learn to our confusion of what tiny

dimensions it is when compared with the entire wheel's vast circumference.

And yet through all our journeyings the sun grows no larger. It remains forever the same small disk of light, only a millstone in breadth, and we could find many a nook and corner of this great world that we call the earth where it could be tucked away and made to sink from sight.

True Greatness of the Earth. Such is the verdict we arrive at if we trust to appearances alone. And respecting one of the two bodies compared our verdict is correct and stands justified by the facts. The earth, our residence, is indeed a body of no mean dimensions. It is by itself a world, a universe, spacious enough to accommodate with room to spare the thousands of millions of human beings who now inhabit it, vast enough to have been the sole theatre of action for all the myriad events of human history.

Once on a time its western boundaries were the pillars of Hercules towering above Gibraltar's straits. Then they were moved farther on, to San Salvador, and later to the Golden Gate of the Pacific Coast. Then they advanced six thousand miles across an island-dotted ocean to the rich empire of Japan. Only then had far Cathay been reached from the east which Marco Polo in the thirteenth century had reached overland from the west. West and east had met and were one.

Earth's Greatness and Our Littleness. The globe had been encircled and what a mighty sphere it was! 25,000 miles in extent its girdle, so the measurements told us, and its diameter through the earth's centre, from rim to rim, a round 8,000 miles. Our

deepest mines, our profoundest excavations, scarcely exceed one mile. Shall ever the remainder of the vast interior be explored? We skim the surface, we make here and there a dent, and we fondly think we have completed the exploration of the earth and have nothing more to learn. But now and then an earthquake or a volcanic blast rends the crust and confounds the littleness of our science. Mother Earth reveals her own immensity. Yes, such is the earth, a mighty body, constructed on a scale so vast that nature's most awful cataclysms cause her no lasting injury, but leave her stable as before. When the fiery storm has passed, she can still boast her unshaken continents and her everlasting hills.

The Sun a Rival in Greatness? But high above the earth shines on the refulgent sun. He, too, is everlasting, is he not, like the earth in his age and in his youthfulness. The same luminary that shines on us lit up the earth for our remotest ancestors. And ages before they came, in the dim past when only vegetative life clothed and peopled the earth, the sun was already at his post sustaining the life which, without him, must have perished. Sustaining, did we say? Is it then true that our earth owes such dependence to the sun? Can it be possible after all that the sun is the more important and the mightier body of the two? Wait and we shall see.

EARTH'S DEPENDENCE ON THE SUN.

It needs but little observation to tell us that the earth depends upon the sun in many different ways. Even the most casual and inattentive of observers

can see that the sun is our greatest natural source of light and heat, and the essential condition of all terrestrial life. It is truly the agent set in the heavens by the Creator for supplying the earth with warmth and light, and the requisites of life. It is at once the light-giving and the heat-giving body, and the life-giving body as well, if life be taken merely as a physical phenomenon.

Exaggerations of the Ancients. Inevitable it was that from the very beginning men should look up at this great luminary in wonder and admiration. And not unnatural was it for the superstitious heathen people of old to adore it as a god, one of the most powerful, indeed, and one of the most beneficent in all their Pantheon. Every day this mighty deity drove his fiery chariot across the sky, and before it darkness was dispelled, clouds and mists were rent asunder, and the host of the stars was put to rout. Once an ambitious youth named Phaethon essayed to enter this fiery chariot, to take the reins and drive the horses of the sun. But he paid for his rashness, so runs the legend, with his death.

Not as a divinity would I picture to you the sun, no more than I would deify an electric light, or a raging furnace-fire used to light and warm and animate all parts of some large factory. But with the ancients I would still picture the sun as a huge ball of fire, whose size and power are greater by far than casual observation would lead us to believe.

Prodigality of the Sun's Light. Think of the amount of light and heat that the earth receives from the sun. It comes to us in quantities that are prodigal. Over an entire hemisphere of this vast earth it shines

at once, illuminating all parts almost equally. Were electric arc lights substituted in its stead, they would have to be placed as thick as the leaves of the forest, and even then they might not suffice.

A Bessemer furnace of molten steel is, they tell us, the most dazzling of all artificial lights. In its presence not only strangers, but even the workmen accustomed to its glare, have to shield their eyes with smoked or colored glasses for fear of being blinded. Yet measurements of comparison have been made, which inform us that the light of the sun even as it reaches us after travelling an unimaginable space, is five thousand times more intense than that of the white glowing mass of molten steel. So superior is the solar orb to all, even the brightest, illuminants devised by man.

Beauty of the Sunlight. How rich and glorious indeed is the light of the sun! How cheerfully it slants across the earth on a clear, cold winter's day, making the very atmosphere luminous, brightening earth and sky and the air that lies between! Even through thick banks of cloud which no other light can penetrate, some of the sunlight makes its way, enough and more than enough to enable me to pursue this writing. And for an hour or more after the sun has set, its second light, its twilight, is still in evidence, painting in gorgeous colors the western sky.

And when twilight has gone and darkness supervenes, how we miss our great luminary! O Earth, thou art dark and black and helpless now; thou hast no native source of light on which thy inhabitants can rely. We go groping about with tapers made to emulate the sun, and with difficulty we find our

way. But patience, only a few hours must we wait. Let us look towards the east, and keep in hope our darksome vigil. Only a few hours and then, lo! the rosy tints in the eastern sky betokening the Morn! So great a being cannot enter unannounced. He must have his advance guard in the form of rosy streamers and banks and clouds of color. And when the guards in orderly and brilliant array have passed to their places, then comes the sun, their chief, calm and serene, resplendent and effulgent, his luminosity unaltered and undiminished, his power as great as yesterday and as on a million yesterdays!

Source of the Sun's Power. Effects as great as these that have been described require an adequate cause. There must be something to explain the wide abundant stream of light that passes unceasingly between sun and earth, and those other floods that are radiated from the sun in all directions, most of them to be lost in space. To duplicate only that fraction of the sunlight which the earth receives, what enormous furnace-fires we should have to enkindle, what hosts of electric lamps animated by a million dynamos! Of what immensity, then, must be the sun's furnace-fires and dynamos or whatever corresponds to these! The sun is indeed a great globe of fire, huge in size, all alive with physical energy, only a small part of whose output is employed by nature to illuminate the earth.

Other Benefactions. Thus far we have seen to what degree the earth is indebted to the sun for the invaluable gift of light. Now let us emphasize the additional fact that we receive heat from the sun as well as light, and in corresponding measure.

A very little reflection will convince us that the earth does not contain within itself the adequate source of the warmth it manifests. True it is that the globe's interior is much hotter than the surface, as volcanos and geysers and other similar phenomena testify. But that this internal heat is not sufficient to maintain at the surface an equable degree of temperature, is evident from the icy cold that attacks the polar regions when the sun's heat is temporarily withdrawn. It is not the interior fires of the earth but the radiant energy of the sun that brings to pass our prevalent genial climate.

Effect of Sun's Untempered Heat. Instead of going into the figures given to express the quantity of heat that the sun lavishes on the earth, let us rather institute a contrast. Think first what would be our condition if there were no clouds, and above all no night to mitigate the ardor of the sun's rays. Suppose, moreover, that these rays descended not only incessantly but vertically downward upon some one portion of the earth.

From the discomfort we now experience on an extremely torrid day we may argue the result. Is it not probable that in the circumstances supposed, every bit of plant life would be parched and burned to a crisp, and that even great forest fires would be enkindled that would sweep unconquerably over the face of the globe?

Effect of Its Complete Withdrawal. Meantime, on the opposite side of the earth would reign perpetual night, with its necessary attendants of cold and gloom. Withdraw entirely the heat influence of the sun, and in a short time the oceans, wide and fathomless as they

are, would be frozen throughout their whole expanse and to their lowest depths. Such imaginary pictures teach us, perhaps better than mere figures could, the extent to which the earth is indebted to the sun for the warmth that prevails at its surface. Happily for us, both pictures are imaginary. A wise and beneficent Providence, employing the sun as His agent, gives to the earth that mean of heat which makes of it a habitable world.

Sun a Life-Sustaining Agent. Not only for light and heat is our globe dependent on the sun, but for vital force as well. Observe how, when winter comes, the vegetative world is doomed to death or a state that simulates death. And winter means not that all the sun's assistance is withdrawn from the earth, but only a part of it, probably less than half. The days are shorter and the sun's rays reach us more obliquely. We suffer only a diminution of the solar influence, not its complete extinction.

But even this partial loss is enough to cause in the vegetative world the semblance of death. The sap is frozen in the veins, no new leaves are born now, even in the evergreen trees, still less is there blossom, new fruit and seed. All plant life is stagnant, till the sun mounting higher in the heavens and lengthening the days ushers in the spring.

Loss Felt by Animal World. Meantime animal life, too, feels in its veins the benumbing influence of the sun's partial withdrawal, and some succumb, the old and the infirm. But the majority contrive to survive the winter's rigors, for animal exercise keeps the blood acoursing, and their strong nature is fitted to endure the partial withdrawal of the sun's helpful

influence. But let winter be prolonged everlastingly and with all its polar bitterness, what plant-seed could survive, what animal could endure? And let the sun's life-giving rays be taken from us, not partially but wholly, who shall calculate how short the time before the earth would be left barren and destitute of life? A few months only at the most would pass before every living being whose life is merely physical would sink into an eternal sleep that should know no awakening.

Abundance of Terrestrial Life. So absolutely is terrestrial life conditional on the continuance of the sun's benign assistance. When now we think of the redundancy and plethora of earthly life, its all but countless forms and in its every form its all but countless members, then we begin to realize the weight of the earth's indebtedness to the sun. And then there begins to come home to us a realization of the stupendous, mysterious power that the sun contains.

Even now not all the gifts have been mentioned for which the earth is debtor to the sun. But enough has been established for the purpose of our argument. A summing-up would evidence that except for the aid of the sun, the earth would be without light, without appreciable warmth, and in its every region without life. Shall we still estimate the volume of the sun as that of some fire-balloon hung in the sky? Can we any longer believe it inferior to the earth in size?

The Argument. Not from one body to its equal goes out such influence so steadily maintained. From higher to lower temperatures heat always flows, from more luminous objects to less luminous proceeds the light. To warm and illumine and vivify the earth

in the manner that actually obtains, to do this even for a single day, would require a globe paralleling the earth in size. To accomplish this indefinitely without cessation requires a globe immensely larger to serve as the sufficient storehouse for the needed energy. All the more as these same mighty influences are not directed towards the earth alone, but sent out in all directions to all the planets and to the emptiest parts of space.

Thus from purely descriptive considerations, we are made ready to accept the figures that astronomers give for the diameter and volume of the sun. They have measured for us this great orb, as they have measured the earth. And they tell us that in diameter it exceeds our planet more than a hundredfold and that its volume is great enough to encompass more than a million earths.* Such is the vastness of its scale; such is its superiority of magnitude over the terrestrial sphere. Only such preponderance of mass and volume could account for the dominance it exercises.

Conclusion. And now let us reverse our first judgment founded on the appearances of things. Scepticism aside, for it is unreasonable, let us acknowledge the sun incomparably the greater of the two globes, and our earth a ball of relatively insignificant size, small enough, indeed, to be tucked away in some corner of the sun and lost to view.

But, wonderful to relate, the greater body waits upon the lesser. The sun serves the earth rather than the earth the sun, as all our argument has demon-

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* See Appendix.

strated. For the lesser globe it is that has been designed to be the residence of man. And in man are faculties and forces of a quality indescribably above all that the sun displays. The light of his intellect is superior to the light of the sun, the energy of will-power to the energy of heat. And the physical life which alone the sun can foster is surpassed beyond comparison by the spirtual life that is every man's birthright. Of more consequence than the sun, or than sun, moon and stars combined into this material fabric we call the world, is any and every human being "made in the image and likeness of God."

CHAPTER III.

THE ROTATION OF THE EARTH.

Nothing perhaps has ever given us a greater shock of surprise than when we were informed for the first time of the daily rotary movement of the earth. Years ago some teacher in a class of physical geography told us of it, and when he or she described the rotation of the earth, we rubbed our eyes in wonder.

Even now there are, perhaps, some who have not yet recovered from their first shock of surprise and and still shake their heads in doubt when it is affirmed that this great globe of ours turns round upon its axis once every day. True, the assertion of the earth's rotation is made again and again, but asserting a thing does not make it so. As rational beings we should examine for ourselves this cardinal point in astronomical science to learn on what grounds it rests. Incidentally we shall learn that it was a Catholic priest who first revealed it to the world of scholars.

ARGUMENTS AGAINST ROTATION.

Earth's Apparent Repose. The first evidences at hand are all of them, everyone must admit, against the supposition of the earth's rotation. For barring superficial changes of relatively slight account, we see

in the earth no sign of motion whatever. The earth is so firm and stable that we are disposed to take it as the symbol of perfect repose.

If there is one thing in nature that seems to be at rest in space, that object is the earth. We see animals and men flitting about on its surface, trains and other vehicles rushing nervously hither and thither, and vessels driven by wind or steam ploughing the deep. But the ground beneath our feet seems firm and motionless and we call it so; and the oceans, though restless, remain confined within their allotted borders. If the earth itself is hurrying on, why do not buildings topple over and fall, especially those sky-scrapers that seem poised in such unstable equilibrium?

Swiftness of Its Asserted Motion. And yet we are asked to believe that the earth is not only in motion but in such rapid movement as no locomotive could ever hope to rival. Though but plain men in the street, we can handle the figures involved as well as could the most advanced mathematician or astronomer. For the assertion made is that the earth turns completely round upon its axis once in every twenty-four hours. And both astronomers and we agree that the equator of the earth measures 25,000 miles. Now all this means that if my station is on the equator, as at Quito in South America, I am being whirled through a circle of 25,000 miles in every twenty-four hours, that is, at an average speed of over a thousand miles an hour. Is it possible that I can be hurried along at such tremendous velocity and have no consciousness of it?

Granted that the speed will be somewhat less at my actual station here in Boston, the rate being re-

duced about one-half, there still remains a velocity of five hundred miles an hour, and in some way I contend, still sceptic that I am, that this swiftness of motion ought to make itself perceptible.

Ptolemy's Objection. Moreover if it were true that the earth is circling about so swiftly, would not its atmosphere be left behind, and as we tore our way through it, would there not result a constant and terrific hurricane that whould sweep the earth clean? A speed of one thousand or five hundred miles an hour would seem to necessitate a contrary wind of parallel velocity. Except the houses built on rock, what objects at the surface could withstand the force of so violent a tempest?

Ptolemy it was, was it not, who first suggested this argument of "the great wind," and did not his argument continue unrefuted throughout the Middle Ages? I will stick to Ptolemy, so concludes the average man, and believe with him that the earth is a motionless sphere. For all the evidence of my senses and my reason points that way and I will need powerful arguments to convince me of the contrary.

The Other Side. So runs the plea for the defense, sounding so plausible that the jurymen make up their minds at once what their verdict shall be. But suddenly the plaintiff's lawyer, in this case Copernicus, a Catholic priest, begins his brief, with his first word unsettles the equanimity of the innocent jurymen, and proceeds with steadily increasing power to persuade them of the falsity of his opponent's reasoning. Like the innocent jurymen we also must listen to him and strive to keep pace with him as he delivers his plea.

ARGUMENTS FOR ROTATION.

Motion Not Self-Revealing. The argument for the rotation of the earth starts from the perfectly certain though somewhat elusive fact that motion never reveals itself directly. Motion is one of the few things in nature that have no voice and deliver no message. If I set myself in motion I am made aware of it, to be sure, by the exercise of my own muscular activity. But if without my effort I am borne along quietly and without jar or commotion, it can easily happen that I shall be absolutely unconscious of my forward movement in space.

Let me suppose, for example, that I am a passenger on the Empire State Express, which makes the trip between New York and Buffalo in the short interval of eight hours. Many a time in this journey the train will be bowling along at the rate of more than sixty miles an hour. But I converse and read my paper and eat my noonday meal aboard the swiftly moving train with almost the same degree of comfort as if I were pursuing the same occupations in my room at home.

Along level stretches of track the illusion is completest. Make the motion smooth enough, how swift soever it be, I, a traveller, will experience the same sensation of repose as if the train were standing still. Only by looking out of the car window and witnessing trees and poles and signal towers dashing by, do I wake to a sense of my exceedingly rapid flight.

Illusion on the Sea. The illusion is even more complete aboard an ocean steamer. For the yielding waters beget less friction than do the steel rails. If I stand

on deck in full view of the water, I can then, to be sure, behold the churning of the water at the prow and the waves rushing madly by in precipitous flight, and if I keep my wits about me I may infer correctly that it is I that am moving and not the waves. But let me go below and sit in some cabin where no view of the ocean is possible, then shall I not only have no sensible evidence that the vessel is moving forward, but if I am suddenly asked in what direction we are travelling I may easily point the wrong way. Yet all the time the steamer is making twenty knots, and in one direction only.

The Argument. Illustrations like these prove how powerless motion is to reveal itself directly. Irregular, interrupted, jarring motion, this indeed has the power of making itself known. For when the speed is checked I topple forward, and when it is suddenly increased I am thrown backward. But if the motion is perfect, if it is made regular and uniform and without change in amount or direction, then other things may tell me of it, but the motion itself never will.

And now perhaps we can understand why we have no sensible direct evidence of the earth's rotation. Grant for the sake of argument that the earth is rotating even at high speed, with only the proviso that the speed is well-regulated and uniform, by no possibility can I feel its motion nor will there be given me any direct evidence of it whatsoever.

Indirect Evidence. It is not to direct evidence but to indirect that we must turn for the proofs that in the earth there is a movement of rotation. The answer to the question of the earth's rotary motion is to be read, not in the earth itself, but in the stars and sky.

Everyone knows that the sun appears to revolve about the earth as a centre once in every twenty-four hours. Its rising, culmination, and setting are so many incidents in its daily round. Nearly all have observed also that the moon traces a similar orbit, though its journey occupies a somewhat longer time. And they that watch the stars from hour to hour of the night have learned that they too rise, culminate, and set as do the sun and moon, and in approximately the same time. Viewed as a unit, the heavens above present the spectacle of a massive sphere turning on an axis in a period of one day. From this set of facts Copernicus derived his argument for the actual rotatory movement of the earth.

Two Possible Explanations. This common progression of all the objects that fill the sky may be real and actual and, if so, the theory of the earth's rotation is nullified. But it may be only apparent and illusory due to the circular motion of the earth. For if the earth be in rotation, it will by an unavoidable illusion cause the whole celestial sphere to seem to rotate in a contrary direction. Concede for the sake of argument that in each twenty-four hours the earth rotates on an axis from west to east, then the heavens will apparently be set revolving from east to west in the same period. Is it not true that every motion whatever begets a similar illusion?

In a word, the diurnal movement of sun, moon, and stars in a common direction from east to west, is perfectly met by either of two hypotheses, one that the movement is actual and inherent, the other that the celestial bodies, of themselves motionless, are set in apparent revolution by the actual rotation of the earth.

The More Probable Theory. It remains to ask which of the two hypotheses is the more probable. To make up our minds, we have but to think of the diminutive size of the earth as compared with the hugeness of the entire celestial sphere.

On the one hand, we have the earth, proportionally only a speck in space as even Ptolemy admitted, and on the other the entire universe of bodies, the earth alone excepted. Among these other bodies is the sun, which we have found to be gigantic compared with the earth. The celestial sphere contains, besides, the multitude of the stars. How far away are they? Evidently not near enough to the earth to fall towards its surface. How large are they? Large enough at least to have remained burning unconsumed throughout the length of human history. How numerous are they? The naked eye counts them by thousands, but the telescope numbers them by millions and tens of millions.

Now is it within the range of probability that all these celestial bodies are physically subservient to the earth? Can it be their appointed rôle to achieve each day a revolution round a body so insignificant in size? Shall tens of millions of bodies be made the satellites of one? Shall the sun and other giant masses of the heavens attend upon the earth, a pygmy?

Enormous Speeds Postulated. The argument against an actual diurnal movement of the entire heavens is already strong, but it appears constantly more cogent the more we give it thought. Think, for example, of the rate of speed which such an hypothesis attributes to the stars! If the earth rotates, its equator speed of 1,000 miles an hour is already enough to astound the

average thinker. But if the heavens are in motion and not the earth, then the very nearest of the stars, were it only a mile away, must travel at still higher speed. And the speed required will increase mathematically with the distance from the earth's centre.

Thus to the moon, the nearest of celestial objects, would be imputed a velocity sixty times 1,000 miles an hour, for sixty to one is the ratio of its orbit with the circumference of the earth. Project imagination into space to the distance of the sun, and figure if possible the size of its orbit and the consequent speed of its daily revolution. Go yet farther into space, out to the stars that lie on the boundaries of the universe, some of them so distant that no telescope has yet discovered them. The farther away, the more enhanced the speed. Even with the vaguest knowledge of star distances, we soon come to the conclusion that if the heavens actually turn as they appear to do, we must ascribe to the stars a velocity that is all but inconceivable.

Harmony of Movement. And all the celestial bodies, whatever their distances, are made to move as one. The more remote are brought into accord with the nearest. The stars preserve always the same alignment. More incredible even than the tremendous velocity that would be needed is the supposition that ten million bodies at unequal distances from us should go round and round at such harmonious rates as always to present the same groupings and the same unaltered formations.

But make the simple supposition that the earth is rotating once each day and the unity and harmony of the celestial motions is at once explained. Assign

but this single motion to the earth, and the common movement of the great celestial sphere must follow as an inevitable necessity. Deny it, and there is postulated for those other worlds, the sun and stars, a movement so terrific and yet so well-ordered that it is absolutely unimaginable. The number of stars now known to us is in the neighborhood of fifty millions. The chances in favor of the earth's rotation, then, are as fifty millions to one.

The Argument Summarized. This is the principal argument in favor of rotation. Stated briefly, it tells us that it is far more probable that our earth is in rotation than the immense unmeasured heavens with all the bodies they contain. It was the argument of Copernicus, the illustrious priest-astronomer of the sixteenth century, and presented by him to the world, it effected a revolution in human thought. For fourteen hundred years men had accepted the doctrine of appearances, believing with Ptolemy that the earth is stationary and the skies are in motion. Copernicus, by establishing and proving the rotary movement of the earth, started a new epoch in the science of astronomy.

Additional Proofs. To the argument of the priest-scientist we are able now to add two others, thanks to the use of modern instruments. The first is an argument of analogy, vouchsafed us by the revelations of the telescope. The telescope shows us conclusively that certain bodies in space are in rotation. There is positive evidence of this for the sun, the moon, and the planets Mars, Jupiter, and Saturn. The evidence is so precise that in each case we can measure the rotation-time.

The rotation of a sphere is, then, not an unknown thing in nature; it is very probably nature's common law. For could we examine the other heavenly bodies favorably, we should probably observe in them the same phenomenon. The only celestial bodies favorably placed for observation are seen to revolve on an axis. By analogy we esteem it highly probable that the earth, a globe like these, is endowed with a movement of rotation.

Pendulum Experiment. The second new argument is based on the famous pendulum experiment, first performed by Foucault at Paris in 1851, often repeated since and always with the same results. The experiment consists in hanging a very long pendulum from the roof of a high building and setting it swinging. As it swings, it is made to trace its course in a bed of sand spread beneath. By nature's law the pendulum continues to oscillate in an unaltered vertical plane. But the sand bed which it grazes is found to turn with the rotation of the earth. As the hours slip on, the pendulum is seen to trace in the sand not one single line, but a series of intersecting lines like the several diameters of a circle.

Only a displacement of the earth from its first direction can explain this resulting pattern of intersecting lines. The pendulum experiment supplies an argument we could scarcely have hoped for, an observational proof of the fact which Copernicus had alleged.

Epitome of Reasoning. Such is the trend of the argument, first, the fact that motion never reveals itself directly and that in its regard we are often the victims of illusion; secondly, the marked disparity

of size between the earth and the heavens; thirdly, the analogy of other bodies in space; and, finally, the observational proof from the movement of the pendulum. If we take reason and not appearance as our guide, we shall not hesitate. There are few facts in nature for which we have a richer cumulus of testimony than the rotation of the earth.

CHAPTER IV.

EARTH'S REVOLUTION AROUND THE SUN.

The sun shares, of course, in the apparent daily revolution of the celestial sphere. Like all other bodies of the firmament, it rises, culminates, and sets, once in each day. But it apparently has in addition a proper motion of its own. It is not always attached to the same group of stars, but journeys slowly through the constellations, in a very definite orbit, however, and with uniform speed. Effort should be made to understand well this particular movement of the sun, for from it we infer the most important truth in the whole science of astronomy, the fact of the earth's annual revolution.

Some Motions Easily Visible. Strange to say, among all ordinary celestial motions the special one of which we now speak is the most difficult of discernment. That the moon is changing its position among the stars, can be learned without any difficulty by simply watching its course from night to night. From one evening to the next, it will be seen to have shifted its position towards the east by the considerable distance of thirteen degrees, a space equal to twenty-six times its own diameter.

The movement of the planets also is, if not easy, at least not difficult to discern. For when they shine,

they are accompanied by certain groups of fixed stars in whose midst they are placed. And watching the planets for a certain period, we shall see them slowly or quickly dislodging themselves from their first positions and entering new groups of stars. It requires but little careful watching to convince ourselves that Mercury, Venus, Mars, Jupiter and Saturn are wandering or planetary bodies. And they have been known as such from time immemorial.

Discernment of Sun's Movement. But with the sun the case is different. For when it shines, the background disappears, the stars flee apace or fade into obscurity, and we have left no visible guide-posts by which to plot its course. But it is advancing on the stars none the less, in the same direction as moon and planets, namely towards the east, and in approximately the same path. And could the sun be eclipsed once each day, thus permitting us to view the particular stars by which it is environed, then we should have ocular evidence of the sun's independent movement. We should then behold the solar orb moving steadily forward in its allotted path at about the rate of one degree a day, twice its apparent breadth, and completing the circuit of the heavens in exactly one year.*

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* An easy way of proving to one's own satisfaction that the sun is thus moving is to notice the stars on the meridian at midnight. At that moment the sun is on the opposite meridian. Now the meridian stars at midnight are never quite the same from night to night. Every star advances towards the west night by night at the approximate rate of one degree. A little reflection will show that this is due to an independent motion of the sun towards the east amounting to about one degree a day.

In view of the difficulty of detecting the sun's change of position among the stars, it is remarkable that it was discovered so early in the history of our race. What man first discerned it and in what epoch we do not know, for the discovery belongs to prehistoric times. But however and by whomever made, the discovery of the sun's independent motion marked, as Newcomb justly says, the birth of the science of astronomy.

Knowledge of the Ancients. Indeed, the knowledge of early peoples concerning the sun's journeyings was much more complete than has thus far been intimated. They knew accurately the groups of stars through which the sun pursued ever its unvarying way. These constellations, twelve in number and of all stellar groups the chief in interest, formed what came to be know as the Zodiac, and are the twelve whose symbols have been placed in the hallway of our Boston Public Library.

Not alone its zone of movement had been determined but its exact line as well, and on their astronomical globes the ancients could draw a line representing perfectly the orbit of the sun. This path they called the Ecliptic, for only on this line could eclipses occur. The two points where the ecliptic crossed the equator of the heavens they called the Equinoxes, the vernal and the autumnal, for when the sun reached either of these points, the night (in Latin nox) was equal to the day all over the globe.

Day by day at regular pace the sun advanced along this orbit, always approximately one degree, until at the end of exactly one year it had completed the round of the heavens. It will help us much

in our consideration of the sun's movement if we can realize as keenly as did the ancients that back of and around the sun there always lies a certain group of stars, some one determined sign of the Zodiac, which would shine forth and appear of a definite figure were it not for the sun's superior light.

Inference of the Ancients. That the sun's movement thus described was actual and inherent, the ancients never for a moment doubted. For them phenomena meant reality and their only doctrine was that of appearances. And the belief of the ancient world was crystallized in Ptolemy's great book of the second century, "The Almagest," in which it was taught that our earth was the centre of the annual revolution of the sun, as it was also the centre of the diurnal movement of the entire celestial sphere. In the order of movement they gave supremacy to the earth, around which as parent body the sun must revolve.

ARGUMENTS FOR REVOLUTION.

Theory of Copernicus. It was reserved for Copernicus, priest of the fifteenth and sixteenth centuries, to undermine this belief of the ancient and medieval world, by asserting the merely apparent character of the sun's movement among the stars. He showed conclusively that all the phenomena could be adequately explained by the mere supposition that our earth is the revolving body, moving forward in space in a large circular orbit whose centre is the sun. Thus he wrested from the earth the place of honor, transferring it to the sun.

Not lightly or without question should we admit a supposition so strange. Again there comes to our minds the thought that if the earth is thus altering its position in space and at a rapid rate, some sensible impression should arise to make us conscious of it; all the more that we are now assigning a second motion to the earth, a forward march through space superadded to the movement of rotation previously established. Though one holds true, the other does not follow, and we must examine its claims as questioningly as if it stood alone. Appearances witness to a stationary earth, and establish in us a prepossession which only the most cogent of arguments shall be able to eradicate.

His Arguments. The argument of Copernicus favorable to the revolution of the earth was drawn from the apparent motion which actual motion never fails to produce. No body whatever can be set in motion without begetting in neighboring objects the apparent effect of movement in a contrary direction. To our sense of sight the illusion is complete; only by reasoning can we get rid of the false impression and distinguish correctly between the genuine motion and its counterfeit.

Analogy of a Vessel. Imagine, for example, a vessel patrolling a harbor at night surrounded on all sides by the harbor lights and the beacons gleaming from the shore. As the boat progresses, every separate light within range of view seems veritably endowed with onward motion. Let us suppose that the vessel in which we are interested describes a wide circle around some island on which is mounted a powerful beacon light. Let this particular lighthouse be the centre of our study.

As the ship advances, the lighthouse assumes continually new positions on the horizon. Now it is set against Winthrop to the north; describing a quarter circle, it is seen to the west projected against Boston as a background. Now it has moved to the south and has found in Quincy or Weymouth its temporary setting, and now it is backed by the promontories to the east, those of Hull and Allerton. Finally, when the vessel has completed one lap of its journey, the beacon light is again in its original position, projected against the highlands of Point Winthrop. Meantime the actual motion of the ship has been so quiet and regular that the passengers aboard thought themselves at rest and of necessity transferred to the beacon light the motion that was their own.

Application of the Analogy. If now the analogy be applied, the beacon light becomes the sun, the moving vessel is our earth, and for the background of the harbor-shores is substituted the belt of constellations that we call the Zodiac. The sun's projection on the Zodiac at any moment will depend on the position of the earth. As the earth moves, so must the sun appear to move in an orbit that parallels the earth's actual orbit in every particular. In direction and in rate of speed the sun's revolution will be a perfect replica of the earth's.

The earth's passengers, moreover, all the while will of necessity be unaware of their own forward progress, and if questioned will answer unhesitatingly that the motion belongs to that brilliant beacon set in the heavens. The analogy holds perfectly and there is no room for doubt that, given a circular motion of the earth, all the phenomena of the sun's apparent movement would be perfectly explained.

Value of Copernicus' Argument. Such was Copernicus' reasoning in favor of the second motion which he accredited to the earth. As it stood, it was but a probable argument and could not generate certainty. It founded a theory, it did not establish a truth. To beget certainty it needed the reinforcement of other arguments, which happily were not long delayed.

It was in 1543 that from his death bed, Copernicus published the book containing the enunciation of his two propositions, that the earth rotates on its axis and revolves about the sun. As a loyal child of the Church he dedicated his work to the then reigning Pontiff, Pope Paul III.

LATER PROOFS.

Argument from the Planets. Within little more than fifty years from that date, a host of new facts had been discovered by a trio of eminent astronomers, Tycho Brahe, Kepler, and Galileo, on which was to be based another and better argument for the earth's revolution. These facts bore on the group of planets called Mercury, Venus, Mars, Jupiter and Saturn. An integral part of the Ptolemaic theory had been that these planets revolved about the earth as did the sun and moon. For this reason Ptolemy's system was called the geocentric or earth-centric, because it made the earth the centre of all celestial motions, ordinary and extraordinary.

What a blow it was to this entire doctrine when it was learned beyond all fear of error that the five planets in question are revolving about the sun and not about the earth! More accurately than his predecessors, Tycho Brahe measured the orbits of these five important luminaries; Kepler reduced the

calculations and combined them into a system; and finally Galileo showed with his telescope the phases of Venus, an irrefragable proof that this planet at least was coursing about the sun.

Copernicus Confirmed. When the three scientists mentioned laid down their pens, there was no further room to doubt that the sun was the focal centre of the orbits of the five planets from Mercury to Saturn. Could it still be true that the sun with its five attendant globes was but a satellite of our earth? Was it not more likely that the earth was a planet also?

The sun was proved to be a centre of five motions. Why not probably of a sixth as well? The sixth body, the earth, lay right in the midst of the group of five, two of them, Mercury and Venus, being plainly nearer the sun than was the earth, and the remaining three farther away. The entire arrangement could suggest only the conclusion that the earth is truly a planet, as much so as Venus or Mars, and that around the sun as a focal centre the earth pursues its annual journey. Thus was Copernicus' theory corroborated by the findings of his successors.

Sir Isaac Newton. Just a hundred years after Copernicus and within a year of Galileo's death, there was born another genius, Sir Isaac Newton, who, before his life was ended, would give to the world his law of universal gravitation. By this law he was to set the crown on the labors of his predecessors. The mathematical work had been completed, so well and accurately indeed that Kepler could draw on a chart a series of closed curved lines representing faithfully the paths of all the planets. For Newton it was reserved to discover the force in nature that

obliges the planets to follow just such orbits in preference to all others. This force was universal gravitation.

Effects of Gravitation. If the moon revolves about the earth instead of following, as it naturally would, a straight undeviating path, it is in virtue of the earth's greater mass and superior attraction. If Venus or Mars circles about the sun instead of pursuing a rectilinear course as the first law of motion would demand, there must be as for every circular motion some central force holding the planet in check, and this central force is the sun's superior attraction.

In the dynamic order, the lesser body always waits upon the greater and, unless too distant, is drawn by it away from its original direct path into a curvilinear orbit at whose focal centre is the greater body. Gravitation, in a word, makes the planetary orbits to be what they are, permitting no exception.

Application to the Earth. And now it is timely to recall the results of an earlier chapter of this volume in which it was shown that the sun is a globe over a million times as voluminous as the earth. In the amount of matter contained, the ratio is indeed somewhat less, but it still leaves the sun preponderant over the earth by three hundred thousand to one.

According to nature's law, then, and in keeping with all analogies, the earth must revolve about the sun. The sun's superiority demands it, not merely as a congruity, not merely as something fit and becoming, but as a necessary consequence of nature's inexorable law. The law of gravitation holds everywhere else, determining the courses of the planets and of their smallest satellites. It must apply also to the earth,

and obedient to it the earth shall pursue in regular controlled orbit a yearly revolution around its dominant body, the sun.

Still another proof of this cardinal scientific truth is found in text-books of astronomy, derived from the phenomenon known as the Aberration of Light. But it is quite too difficult to be unfolded in a popular presentation such as this is meant to be. Suffice it to say, that the new proof confirms by an appeal to fact all the considerations here brought forward.

Summary of the Reasoning. Our effort in this chapter has been to summarize the triple argument in favor of the earth's forward movement in space. Contrary to our sensations this motion seems, but what mere argument of sense will stand before such a cumulus of testimony? Reviewing the evidence, we find that there are three separate lines of demonstration: the argument from the ease with which our senses are deceived in the matter of real and apparent motions; the argument of analogy drawn from the observed revolutions of the planets; and the proof from relative size and consequent attraction under the law of universal gravitation.

From a daring speculation the theory of Copernicus has grown into an established truth. If the first observation of the sun's independent motion marked the birth of the science of astronomy, his correct explanation of the sun's independent motion marked no less truly the rebirth of the science. His enunciation of the earth's revolution was a triumph of astronomy, opened a new era in the study of the heavens, and by solving one part at least of the puzzle of the firmament proved its author a prophet and a seer.

CHAPTER V.

NICHOLAS COPERNICUS.

From many points of view the career of Nicholas Copernicus is worthy of recital. He is quoted in nearly all text-books and manuals of astronomy and always, where comment is added, in terms of highest praise. Authorities as competent in their field as Newcomb, Ball, and Miss Agnes Clerke, to mention but a few of many, do not hesitate to bestow the title great on the man himself and on the system which he elaborated. And despite later revisions, the modern system of astronomy continues to bear his name.

He belonged to a period of history remarkable for its many-sided accomplishments, and, as it appeared at the time, critical for the life of the Church. He lived in the full flower of the Renaissance, and was the contemporary of Columbus and Luther. Columbus gave to the world a new hemisphere, Luther gave to the world far less happily a new religion, fortunately failing in his attempt to dispossess the old, and Copernicus simultaneously gave to the world, as a contemporary bishop expressed it, a new heaven and a new earth.

Sources of Information. To trace briefly the life of such a man is quite pertinent to our purposes, and

may be regarded as opportune, now that his astronomical system and its proofs have been sufficiently described.

Obscurities of detail are to be expected in seeking to learn completely the life-history of a man of his modesty and self-effacement, living moreover in an era when biography was cultivated less than now. There are missing important data needed for the complete exposition of his life. But the main outlines are clear, and earlier errors have been corrected and interstices supplied, thanks to special studies of the past decade. In two excellent recent volumes from Catholic authors, Walsh's Churchmen in Science and Volume IV of the Catholic Encyclopedia, may be found good summaries of what is now well ascertained of the life of this important figure in the history of science.

His Family and Country. Copernicus' life covered a period of seventy years, spanning the fifteenth and sixteenth centuries. He was born in 1473 in Thorn, now of eastern Germany, and died in 1543 at Frauenburg on the Baltic coast, also at present a town of eastern Germany. He was more likely, however, of Polish ancestry and blood than German, at least on his father's side.

The family were not merely loyal but devout Catholics, giving three of four children to the direct service of the Church. Moreover, his maternal uncle was a bishop, and to the guidance and resources of this prelate, Nicholas owed the remarkably extensive education which he received.

Extent of His Education. His entire schooling from the age of ten, when he lost his father by death,

was directed by his uncle, and it was not completed till he had passed his thirtieth year. He made his college course at Cracow in Poland, repairing thither when eighteen years of age. At twenty-four he left Cracow for Bologna in Italy to pursue studies of university rank. Here he met the astronomical teacher, Novara, who though himself a follower of Ptolemy, first suggested to the youth's mind that the correctness of Ptolemy's system might fairly be investigated.

In the year 1500 he was at Rome attending the Jubilee celebration, and incidentally delivering some lectures on his favorite science. From 1501 to 1503 or even later, he added to his store of knowledge by following courses in medicine and jurisprudence at Padua and Ferrara, taking the degree of doctorate in Canon Law at the university of the latter city. When he returned to his natal country in 1505 or thereabouts, he was unquestionably supplied with a rich mental equipment. Few there are today that might not envy his educational opportunities. And these were allowed him, be it remembered, at a time when all education in Christian Europe was under the auspices of the Catholic Church and most of it under her direct control.

His Mature Achievements. The versatility of his mature accomplishments was proportional with the breadth and variety of his education. Remembered chiefly as an astronomer, he was in no sense a narrow specialist but a man of broad culture and manifold occupation. Devoted ecclesiastic, student and teacher of the sciences, practitioner in medicine, and financial counsellor to the State, he was each and all of these,

and in each pursuit won distinction and applause. Incidentally he was by turns, though on a smaller scale, an artist-painter, a writer of verses on sacred themes, and a translator of Greek authors.

VOCATION AND AVOCATIONS.

His Profession. By vocation and profession he was an ecclesiastic. Appointed a canon of the Cathedral of Frauenburg at the age of twenty-five through the influence of his uncle, he retained the post until his death. For many years his studies in Italy and later his attendance on his uncle-bishop at Heilsberg, kept him from actually fulfilling the duties of the canonry. But from 1512 on, with the exception of one interruption of four years, and therefore during all but four of the last thirty-one years of his life, he appears to have served actively and abidingly as a member of the Cathedral chapter.

Was he an ordained priest? Unfortunately we cannot answer this question beyond all cavil, for there is no record of his ordination extant. No more, however, does there remain any record of his medical degree and yet we know he practised extensively the art of healing. Many converging facts insinuate that he had entered the priestly order, and the careful biographer of the Catholic Encyclopedia deems it probable that he had received the sacred priesthood.

His Offices in the Church. His very office of canon would seem to intimate this. Further, in 1512 he participated in the election of the new bishop of Frauenburg. From 1516 to 1520 he was administrator of the diocesan castle of Fallenstein. At the

death of Frauenburg's bishop in 1523, he was made administrator of the diocese. In 1537, he was named by the King of Poland as one of four candidates for a vacant episcopal see. His remains lie interred in the crypt of the Cathedral where he officiated so long as canon.

These numerous facts accumulated make it quite probable that he was of priestly rank. Writers, however, who court scientific accuracy of statement will give to him as certain the titles of ecclesiastic, churchman, and officer of the church, adding, if they have occasion to do so, that he was in all likelihood an ordained priest. And whatever his precise dignity, of his fervor and fidelity in the discharge of his ecclesiastical duties, there is not the slighest reason for doubt or even for cavil.

Relatively Minor Occupations. Without prejudice to his ecclesiastical profession, he practised also the art of medicine. By all who obtained his services in this field, he was rated a skilful physican. It is to be carefully noted, however, that medicine was was not his profession. He practised only privately, never professionally. Rather strange it is to learn that he exercised his medical skill in favor of two classes, the noble or very rich and the very poor. Family friendship was the motive in the one case and charity in the other. That he ministered to the poor always without charge, reveals one of the many admirable elements of his character.

Whatever else we might look for in Copernicus' life, we should scarcely have expected to find an excursion into the field of public finance. But this subject, too, engaged his interest, and beginning in

1522 he wrote a series of financial treatises. They were so excellent that they received instant notice from the ruler of Germany, who thereupon claimed his services as a deputy counsellor of finance. Again without smallest detriment to his true vocation or his numerous avocations, Copernicus discharged acceptably the duties of this additional office during a period of seven or eight years.

ASTRONOMICAL CAREER.

His Interest in Astronomy. Our hero is best known to the world, however, as an astronomer, and in this capacity will be longest remembered. All who know anything of Copernicus are aware that he proposed a new theory of the heavens which was destined to effect a revolution in the teaching of the science. It is in this special rôle, then, that we have now to consider him, inquiring first how large a share astronomy played in Copernicus' life.

If we take life to mean the period of one's mature manhood, then we may say truly that Copernicus' interest in astronomy was lifelong. From his student days until his death, he was not merely interested in the science but devoted to it. The pursuit of this learning was with him something more than an avocation or diversion, it was as it were a second vocation, and might have been called a passion in one less self-controlled.

From Novara, his professor at Bologna, came his first impulse in this direction. His own lectures at Rome in 1500 further strengthened the impulse, determining him to make the astral science his

specialty. And thereafter for a period of more than forty years his astronomical researches went hand in hand with the performance of his ecclesiastical functions.

Reform of the Calendar. Already in 1514 his reputation as an astronomer was considerable enough to have won the notice of the then reigning Pontiff. Leo X thus early had thought of reforming the Julian Calendar which was now proving defective, and appealed among others to Copernicus to assist in the work of reconstruction. The latter, after giving due attention to the project, answered that the time was not yet ripe for reforming the calendar properly.

The request from the Pope spurred him on, however, to an increased ardor for these studies, and impelled him to gather statistics and make computations which were later used when the Calendar was actually revised under Gregory XIII. Thus from Italy and Rome came the second inspiration to make astronomy his lifework.

Preparation for his Magnum Opus. No man of his period was better qualified to undertake the task of reconstructing radically the system of astronomy then in vogue. He was a thorough mathematician, according to one authority the best of his time. He was well versed in Greek, and thus had access to the writings of the ancient masters in their original text. Moreover, wherever he dwelt, he continued to prosecute his studies assiduously, and the towers of Heilsberg, Allenstein, and Frauenburg, availed him as observatories from which to trace and measure the courses of the heavenly bodies.

In announcing his final results he himself testified that they are the fruit of long and laborious observa-

tion. And his epoch-making book gives ample evidence that his observation of the heavens had been untiring.

His Work "in Petto." By the year 1531, when he was now fifty-eight years of age, he had finished his great work, "On the Revolutions of the Heavenly Bodies." The printing of the book, however, was delayed until just before his death, which occurred some twelve years later. But from this delay it would be a mistake to infer that he or his chosen theories were without influence on the astronomical thought of his time.

Although he refrained for well-considered reasons from publishing his new doctrine to the world, he did not abstain from teaching it privately. To a few favored disciples he made known his theory, distributed among them an abstract of his larger work, and through their instrumentality caused the new doctrine gradually to spread. In 1533, a certain scholar made thus acquainted with his views, lectured before Pope Clement VII on the Copernican solar system (note the significance of the title), and was rewarded for his effort with a gift of rare value.

From 1536 on, Copernicus was repeatedly urged by his intimates to publish his work, among others by a cardinal and a bishop. At last yielding to their entreaties, he delivered his manuscript to the press in what proved to be the final year of his life.

Reasons for Delay. Some have interpreted Copernicus' delay in publishing as a clear sign that he dreaded to expose his opinions to the church authorities, fearing ecclesiastical censure if not actual persecution. Andrew D. White, adopting here as

always an extreme view, enumerates Copernicus among the scientists who became victims of persecution at the hands of theologians. But as far as Catholic theologians are concerned, all the facts argue to the contrary. By Luther and Melancthon during his life, and by their followers after his death he was indeed opposed, and his theories were condemned as running counter to the Scriptures. But from his co-religionists, including men of high position in the Church, he received, as has been indicated above, the most ample encouragement and support.

Not fear of persecution but distaste for controversy was his sole motive for delay. He was quite aware that his scientific system was novel and revolutionary. He knew, too, that it might be mistakenly construed as at variance with Scriptural teachings. For fear, therefore, of becoming embroiled in controversies which to his retiring nature would have been most unwelcome, he put off indefinitely the publication to the world of his great discovery. Thus is shattered the charge that Copernicus feared persecution from the Church authorities. The best proof of his confidence and loyalty is that before publishing he added a Preface dedicating his volume to the Holy Father. The dedication was accepted. And the very first parts issued are now in the Vatican library.

Reception of the Work. The story of the manner in which the world received his masterpiece, brings us perforce to the period following his death. It is quite consonant with the history just given. From the start the book was antagonized by some non-Catholic theologians, as he himself had anticipated. But it was absolutely unopposed, as far as we know,

by any Catholic for over seventy years. Then arose the unfortunate Galileo controversy, in which Copernicus' work was inevitably involved.

As an incident of the Galileo case, the book of the master was conditionally condemned by the Congregation of the Index. The Congregation required that eight sentences of Copernicus' text should be altered so as to read that the system there expounded was merely an hypothesis and not yet an established truth. Thus altered, the volume might be read with perfect freedom. Finally, when the time came that the truth was considered to have been definitely established, the condemnatory decree was removed from the Index, this being in 1758 under Benedict XIV, and thereafter the work in all its parts enjoyed complete immunity.

Death of Copernicus. The last narration has brought us far beyond the actual boundaries of Copernicus' life. The flame of his genius had been withdrawn from the world in 1543. Thanks to his own caution, his life had gone on to its close like a tranquil river, unruffled by the storms which reactionary hostility was seeking to arouse. It is a pathetic incident in the career of this venerable man that the first printed copy of his book was brought to him only on his dying day. He was then too weak to read or even see the valued tome, but it was reverently made to touch the dying hands of its author before he should be taken by his Maker to a literally "new heaven and new earth."

His Monuments. On his tomb, says his biographer, is inscribed the epitaph he himself had chosen, "I ask not the grace accorded to Paul nor that given to Peter;

give me only the favor Thou didst show the thief on the cross." Monuments to his memory have since been erected at Thorn where he was born, and at Cracow where he studied. But the most precious of all his material memorials is the monument that surmounts his tomb in his own loved cathedral of Frauenburg.

In the words of Dr. Stoughton, a Protestant divine, there is there "painted a half-length portrait, pale, thin, aged, but with an expression of countenance intelligent and pleasant. His hair and eyes are black; he is habited as a priest; his hands are joined in prayer. Before him is a crucifix, at his feet a skull, and behind him are a globe and a pair of compasses. His devotion, his deadness to the world, and his love of science are thus aptly symbolized."

CHAPTER VI.

THE PLANETARY SYSTEM.

The chief result of the triumph of Copernicanism was to establish the earth among the planets as one of their order and number. This planetary system can now be made the object of special further study.

The beginner in astronomy experiences a just pride when he first learns to locate and identify the planets as distinguished from the fixed stars, and in his use of the telescope he will have no more pleasing experience than his detection through this instrument of such picturesque planetary phenomena as the phases of Venus, the moons of Jupiter, and the rings of Saturn.

Planets and Stars Compared. A merely superficial observation of the sky at night would discover no distinction between the planets and the stars. To the careless observer both would appear indifferently as shining points and would be classed by him under a common designation. But closer study discloses three distinguishing factors, of which two at least are available as criteria for identifying the planets.

The planets are wandering bodies, moving from place to place among the constellations, whereas the stars are stationary or apparently so, maintaining from age to age the same alignment. Further, the

planets are of themselves dark bodies like the earth, appearing bright only because they reflect and mirror the light of the sun; whereas the stars are intrinsically bright objects like the sun or any terrestrial source of flame or fire, appearing lightsome therefore because of their own native luminosity.

The distinction just indicated is the only essential difference between stars and planets. There remains, however, a third difference relatively to us, namely, that in the telescope the planets widen out into sensible disks that look like miniature moons, whereas the stars on account of their extreme distance never enlarge beyond mere points of light, no matter how powerful the instrument employed.

The third test is one that can readily be applied by the possessor of a small telescope to such objects as Venus, Mars, Jupiter, or Saturn on the one hand, and any fixed star as Sirius on the other. Without the telescope one is compelled to fall back on the first test, assuring oneself by observation pursued from night to night that this or that indicated planet, as Jupiter or Saturn, is actually changing its position among the stars.

Arrangement of the Planets. It would be very difficult for the beginner, even after locating the planets properly, to determine the order in which they are arranged. How shall he proceed to learn their relations of position and movement? He must first dismiss from his mind the illusion that they are equidistant with the stars. The telescopic test if rightly apprehended will convince him of the great disparity of distance between these two classes of celestial objects.

The fact is that the planets are grouped together in one part of universal space, and rather closely grouped if comparison be made with the stars. The nearest star is ten thousand times farther from us than the remotest planet. The planets form a group apart centred in the sun.

Within the part of space they occupy, they are moreover disposed according to a well-established order. Some are less distant from the sun than is the earth, as evidenced by the fact that they never come into opposition, that is, they never appear in a quarter of the heavens opposite the sun, as they would surely do if their orbits ran outside the earth's. The planets nearer the sun than we are Mercury and Venus. All the others from Mars to Neptune come sometimes into opposition, appearing in mid-sky at midnight, a proof of their superior distance. The distances thus meted out to the several planets are never changed except within narrow limits. The planets are to be conceived as describing curved orbits of unequal radius around a common centre.

Common Plane of Movement. It is very important for the understanding of the planetary system to learn that all their orbits, wide or narrow, lie almost in one plane. One is never to search for a planet near the poles, nor indeed in any part of the heavens other than the Zodiac. The Zodiac has been previously described as the specific girdle of constellations through which the sun's course runs. In the exact middle of the Zodiac lies the ecliptic, marking the precise line of the sun's apparent journey. On any astronomical globe will surely be found delineated the Zodiac, everywhere sixteen degrees wide, and through

its centre and parallel with its borders the line of the ecliptic representing the sun's apparent path.

The successful search for any planet will always discover it within the boundaries of the Zodiac, and for the greater planets, never more than seven degrees from the ecliptic, usually much nearer. If the ecliptic, which is a great circle of the sky dividing it into two perfect hemispheres could be tipped over and made to coincide with the horizon, another "great circle," then the members of the planetary group whenever visible would be seen on the horizon or hugging it closely. We should then surely say that the planetary orbits lie approximately in one plane. So shall we also as surely conclude if we realize that the ecliptic is, astronomically speaking, as definite a circle or line as the horizon.

It is approximately correct, therefore, to draw the orbits of all the planets on the same flat page, and it is near the truth as well as helpful to the imagination to picture these bodies as so many ships riding on a level ocean in circular orbits of unequal radius around some chosen central island.

Common Direction of Movement. Moreover, all the planet-ships sail over the imaginary ocean of space in a similar direction, having the sun-centre always at their left. Observation of the planets spread over a few months will convince the interested student that their progress through the Zodiac is in a common direction from west to east. Proceeding it is true at unequal rates of speed, they yet march on from Aries to Taurus to Gemini, always towards the east. Or if at times by exception they appear to turn in their course,—for some reader has probably heard of "retro-

grade motion,"—their retrogression can be perfectly explained as unreal and due to the simultaneous movement of our observatory the earth.

The planets' direction of movement is described as counter-clockwise, for such it would be if viewed from the north pole of the heavens. And the adjective may be comprehensively applied so as to describe not only the revolution of planets about the sun but also their axial rotations. And with relatively unimportant exceptions it applies to the satellites of the planets as well, defining the direction of their revolution and rotation. Thus the eight major planets and their more than twenty satellites both revolve and rotate in perfect harmony.

Harmony of the Planetary Movement. There thus prevails in the planetary system a remarkable community of movement both in plane and direction, embodying such order and regularity as we commonly associate with an intelligent author. In contemplating the order observed, it is to be remembered that we are dealing not with tiny lamps but with great globes, many of them comparable in magnitude to our earth and some of them far surpassing it. These giant spheres are placed at very wide intervals, albeit the intervening spaces exhibit almost perfect proportion. There is no intrinsic reason why these massive orbs so unequally placed should agree so perfectly in the line and direction of their march. Apart from a governing law and a ruling intelligence it seems impossible to explain the orderliness of their movement.

The Argument of Design. Long ago philosophers found in the starry heavens a satisfying proof of the existence of an all-ruling and supremely intelligent

God. Their premise was the beauty of the sky and the orderliness of its movements; their conclusion was the Deity. The argument was thus eloquently phrased by Minucius Felix, a Latin Father of the third century: "What can possibly be so manifest, so confessed, and so evident, when you lift up your eyes to heaven, and look into the things which are below and around, as that there is some Deity of most excellent intelligence by whom all nature is inspired, is moved, is nourished, is governed? . . . If on entering any house you should behold everything refined, well-arranged and adorned, surely you would believe that a master presided over it, and that he was much better than all these excellent things. So in this house of the world, when you look upon the heavens and the earth, its providence, its ordering, its law, believe that there is a Lord and Parent of the universe far more glorious than the stars themselves and the parts of the whole world."

What modern astronomy has taught us of the wonderful order prevailing in the planetary system, must be adjudged a powerful reinforcement of Minucius Felix's excellent argument for the existence of a Supreme Deity.

THE PLANET JUPITER.

Just now (Feb., 1909) the planet Jupiter is visible evenings in the eastern heavens, rising a little before eight on the first of the month and a half-hour earlier in each successive week.* When at its best, as it will

* One month later for each succeeding year.

be in the period just ahead, it is many times more lustrous than any of the stars. Even among such companion lights as Sirius, Procyon, Regulus and the like, all of them first magnitude stars, Jupiter is unmistakable by reason of its surpassing brightness.

Here is a planet, then, that the veriest tyro in astronomy can now search for with absolute confidence of success. And when he comes upon it, let him set it down mentally, not as a star that shines by its own effulgence, but as a planet borrowing all its light from the sun; not as a distant stellar world trillions of miles away, but as a near neighbor astronomically reckoned, one of a group that includes our earth; not as an independent primary body like the stars, the centre of whose orbits no one knows, but as a planet tributary and subordinate to the sun, on which it attends and round which it courses.

The Jovian System. In the telescope and even in a good opera-glass, Jupiter presents one of the finest and most instructive of celestial spectacles. Its round disk will appear larger and larger according to the increasing power of the instrument employed, and in a good three-inch telescope will be seen crossed by two parallel cross-bands midway between which lies the planet's equator.

Moreover, there will be found attendant on the planet four moons or satellites. They bear the same relation to Jupiter that our moon does to the earth. Their setting is not only esthetically interesting as being a fine morceau of the Creator's handiwork, but scientifically instructive as being a picture in miniature of what we believe to be the grouping of the entire solar system.

The fact that these four gleaming lights, for such they appear, are always found with Jupiter whereso-ever it wends its way, is a proof that they are not fixed stars but, like their principal, planetary or wandering bodies. To them, indeed, as to our moon the name of secondary planet can be and is applied, their master or principal then being called a primary planet. But moon or satellite is a more distinct term for designating a member of this class of celestial objects.

Arrangement of the Satellites. It will be observed at once that the four moons of Jupiter are not disposed irregularly about the planet, above, below, or on any side whatsoever, but uniformly and systematically along one line. And by reference to the dark bands it can be made out that this line is an extension into space of the planet's equator. No matter when the planet be viewed, the satellites if visible at all will be found stretched along a single imaginary line.

According to our simile of ships at sea, they must therefore lie in a common plane. Little gunboats cruising or deploying about their master battleship, they do not ascend above the warship's height nor are they depressed below it, but remain true to the ocean level. Their orderly maintenance of position is a reminder of what was postulated for the setting of the primary planets. Indeed, the sea in which they sail is merely a portion of the great ocean plane that forms the scene of the larger evolutions of the planet fleet. Expressed technically, the plane in which Jupiter's satellites are located is identical with the plane of the ecliptic.

Their Regularity of Movement. Finally, within this plane their career is not one of sodden rest but

one of vivid motion. And here there is no reference to the forward advance through the star-groups which they share with their principal and for which the latter is responsible. But apart from this common motion, within their own system they assume new collocations and effect new groupings. Now grouped on the same side of the planet, now arranged in pairs at either side, at another time they seem more unsymmetrically distributed, one satellite striving to balance three.

Nor must the amateur astronomer be disappointed if one or two members of the group play hide-and-seek at times behind the planet, for this they must do to pass from one side to the other. Mere casual observation thus discovers that Jupiter's satellites are in constant movement. It needs closer study to discern that their movement is orderly and systematic and governed by a common law, that all these bodies are tributary to the planet, describing round it curved orbits of similar geometrical form and in the direction which we have designated counter-clockwise.

Interest of Their Discovery. Jupiter and his satellites evidently form a perfect system, its members regularly composed and its movements harmoniously ordained. When discovered by Galileo in 1610, the Jovian system was a revelation to the astronomical world. Here in space was plainly an example of a twofold motion, involved and yet not confused. The cycle of the planet about the sun and the epicycles of the satellites about the planet were blended into harmony. The orbits of the satellites were carried forward in the larger orbit of the master planet.

They were the gunboats cutting quick circles, Jupiter was the battleship moving majestically in its large orbit, never relaxing its hold on these tributary vessels.

Galileo's Exaggeration. The Copernican theory had alleged that the terrestrial system, consisting of the earth and its satellite, was revolving about the sun, the earth in a circle or cycle (for they mean the same) and the moon in an epicycle. This was the cardinal principle of the Copernican hypothesis. In the early part of the seventeenth century, Galileo was its most zealous and strenuous protagonist. When, therefore, in 1610 he had descried the satellites of Jupiter and their mode of motion, be believed that he had now at hand a conclusive and compelling proof of the Copernican theory. For the Jovian system fulfilled the conditions which Copernicus had postulated for the earth-moon system.

But it is now quite clear that the argument was one of analogy only, admittedly a striking similitude, and yet no more than a similitude. Now analogy never constitutes irrefragable proof, capable of satisfying the demands of positive science. In the matter of the earth's revolution, scholars were compelled to wait until in the period following Galileo's death Newton should supply the required stringent proof with his law of Universal Gravitation.

In Galileo's day "there were no direct conclusive arguments for the revolution of the earth," wrote Fr. Secchi, and Miss Agnes Clerke has added, Galileo's discoveries were "brilliantly illustrative, although not demonstrative, of the Copernican theory." Let these judgments made by irreproachable authorities be

kept in mind in any discussion of the celebrated case of Galileo.

A Warrantable Inference. The Galileo case aside, our study of Jupiter and its satellites is calculated to deepen our conviction of the reign of law in nature. Not only in its larger lines but in its smallest details the universe is both fashioned and operated according to law. It is most nearly likened to a watch or chronometer, albeit of huge dimensions. Of a truth it is nature's timepiece, on which all of man's similar fabrications depend for their reckoning and their speed.

The Jovian system is one set of wheels in the great cosmic horologe. Study shows that they move and turn in perfect order and with absolute precision. They exhibit a refinement and delicacy of construction that neglects not the smallest detail. No part of a watch but evidences the designer's craft; no part of the universe but witnesses to the intelligence of its First Cause.

CHAPTER VII.

THE NATURE OF THE SUN.

It will not surprise us to learn that almost from the beginning of man's contemplation of the heavenly bodies he was led to inquire into their intrinsic nature. Very early in the history of astronomical science curiosity was awakened and speculation started as to how the astral bodies were composed and what sort of beings they really were.

Until very recent times, it is almost needless to say, the answers to these inquiries could be no more than guesses at the truth and vain surmises. The sun and stars were too distant to allow close study and detailed observation, and the telescope had not yet been invented to bring these objects into closer view.

Ancient Belief. There prevailed among pagan races an almost universal belief that the sun and moon and planets were supra-sensible beings endowed with supernatural powers and, as so many divinities, ruling the affairs of men. Even the most enlightened attributed to them a nature utterly unlike that of the earth. They dwelt in the upper ether; their lightness bore them aloft or sustained them afloat high above our atmosphere. By their very nature they glided easily from place to place, while our earth remained sluggishly at rest. The earth was

constituted of ponderous dull clay, they were of some subtle, intangible substance, wholly unlike everything with which we were familiar. Vague as were the conceptions of the ancients, it is clear that they were persuaded of an utter dissimilarity of nature between the earth and these residents of the sky.

Plausibility of this Belief. Even now we should be bound to cherish similar opinions did we trust to appearances alone. For is it not true that the celestial orbs pursue lightly their course across the blue empyrean like so many incandescent balloons inflated with the lightest of gases? And does not every solid substance, on the contrary, sink as low as possible and fall immediately and rapidly to the earth when released in mid-air?

And is it not true that our earth is of itself dark and cold and motionless, whereas the sky's inhabitants are forever brilliant with light, glowing with warmth and instinct with ceaseless activity? After all, was it so extravagant of the ancients to suppose the denizens of the firmament to be utterly unlike the earth? Shall we dare charge so mighty a philosopher as Aristotle with puerility?

MODERN STUDIES.

Advent of Descriptive Astronomy. With the invention of the telescope in the first decade of the seventeenth century there was given to men an absolutely new source of astronomical information. From that event descriptive astronomy dates its birth. Something more than mere conjecture will from this date be possible respecting the surface features and intimate

make-up of the heavenly bodies. The telescope will reduce markedly the distance of the various objects of the solar system, bringing them into closer range. What light this great instrument has shed on the problem of the sun's nature, we have now briefly to review.

Sun Spots and Their Import. One of the first discoveries made by Galileo with his newly-found implement was that of sun spots, dark patches or areas that appear not infrequently on the sun's shining disk. In the course of time these sun spots were made the basis for a new theory of the sun's nature fully as curious and extravagant as was the opinion of the ancients.

It is only a little more than a century since Wilson, a Scottish astronomer of repute, announced his opinion that the sun is fit for habitation. The part of the sun that we normally see is, according to Wilson's theory, no more than a surrounding atmosphere of intensely white incandescent vapor. Underneath it lies the true body of the sun, solid and non-luminous like the earth and presumably, like the latter, suited to the needs of living beings.

The argument for the theory rested on the phenomenon of sun spots. These were interpreted as being rifts or openings in the solar atmosphere, allowing us to peer through the sun's gaseous envelope and to descry portions of the interior sphere which constituted the true body of the sun.

An Extreme Yet Popular Theory. To the other extremity of its arc had swung the pendulum of thought. From being totally unlike the earth, the sun came now to be conceived as its almost perfect

counterpart. Both were rigid impenetrable globes, differing in magnitude alone, and each might be the secure residence of living occupants. In physical features the sun had been degraded to the level of the earth. The mystery of its being was unveiled. No longer must it be esteemed of superior essence, light, airy and ethereal, but as heavy, compact and rigid as the earth itself. What a descent from the proud estate allotted it by the older philosophy!

Nor was Wilson alone in advocating this now rejected theory. Herschel, his contemporary and the most famous astronomer of his age, gave to it the prestige of his name and the weight of his authority, and Arago, the delightful lecturer of the succeeding period, followed suit and disseminated throughout France the doctrine of the sun's habitability. What a surprise to us now to learn that in the first half of the nineteenth century this theory was a current teaching in the manuals of astronomy!

In Medio Stat Veritas. Correct knowledge holds a middle way between the two extremes. The sun is not totally unlike the earth, nor is it wholly similar. In its chemical make-up it resembles the earth to a remarkable degree, while in its physical condition it is far removed. The ancients were wrong in asserting the sun to be of quite another substance; but Wilson also erred in imagining that the true sun has a superficial topography assimilating it to the earth. To refute these two opposite errors and at the same time to pursue an orderly train of thought, one's study of the sun's intrinsic nature should be arranged under two headings, the chemical and the physical.

CHEMISTRY OF THE SUN.

Chemical Make-up of the Sun. It is the business of chemistry to study the elemental constitution of bodies. With this science as our handmaid we have come to learn the ultimate composition of the things that are in the earth itself and in its waters and in the air by which it is environed. The elements into which all terrestrial objects can be resolved are only few in number, perhaps not over eighty. Their names and classes can be found in any good primer of chemistry.

Now the sun, unlike the earth as it seems, is, nevertheless, similarily composed. The spectroscope, a marvellous instrument, whose proper use dates only from the year 1859, has analyzed the sunlight and compared it with the light emitted by the several terrestrial elements when rendered incandescent. The fruit of this analysis and just comparison has been to reveal in the sun's mass a large number of the selfsame elements that abound upon the earth.

Spectrum Analysis. Remarkable indeed have been the advances of spectrum analysis and wonderful its revelations. Incidentally it may be said that no one had a larger share in effecting this progress than Fr. Secchi, the distinguished Italian Jesuit astronomer. How unexpected and curious it was that by this science there should be found in the sun some thirty or more distinct elements, all of them, with but one exception, identical with the earth's constituents.

It was a triumph of spectrum analysis to show that the sun is like the earth even in the materials of which it is composed. Away now with the ancient speculation that the sun is of some strange indefinable sub-

stance like ether or other suppositious thing. In its stead we must adopt the interesting verdict of modern science that the sun's mass is constituted of the identical materials, the same metals, non-metals and gases, out of which the earth is moulded.

Unity of Nature. More and more as science has progressed, it has taught us the community that obtains throughout the visible universe. All things obey common laws, all exhibit a common plan, all are constructed, as we have just now intimated, of common materials. It is one of the highest problems of natural philosophy to seek to discover the cause of this perfect unity. For us who believe in Christian monotheism the problem is already solved.

Habitability of the Sun. It remains for us now to address ourselves to the opposite theory, that of a century ago, which arguing from sun spots alleged that the nucleus or mass of the sun is a dark body and fit for habitation. The inquiry has a certain human interest, as forming a part of the wider problem of the habitability of the heavenly bodies in general. Many a pen in recent years has been busy with the question of the possibility of life elsewhere than on the earth.

Considerable headway will have been made with the larger problem if we can reach a satisfactory conclusion respecting the habitability of the sun. For all the fixed stars, numbering tens of millions, are indubitably kindred to the sun in their physical nature, and whatever conclusion we adopt anent the sun's fitness for habitation must apply equally to the multitude of the stars.

PHYSICS OF THE SUN.

Its Physical Condition. It is the verdict of Science that the sun, while chemically akin to the earth, is very unlike it in its physical condition. Of physical traits the most important is temperature. All evidence tends to show that the heat of the sun is so intense as to be absolutely prohibitive of the presence of corporeal life. Nay more, the probability is that nothing, not even the hardest adamantine rock, could retain its solid condition if brought to the sun, but must perforce be resolved by the excessive solar heat into a molten or even gaseous state.

In an earlier number of this series attention was directed to the vast quantities of heat that our planet derives from the sun. And by an argument from effect to adequate cause, it was there contended that the sun itself must be a seething mass of fire of far greater volume than the earth. For the earth receives only its quota of the sun's radiant energy, the fraction being less than one two-billionth of the whole. The rest is radiated to all parts of space in amounts capable of vivifying two billion planets set at the same distance as our own. Yet, nothwithstanding this enormous output of thermal energy, the original power of the sun has remained undiminished, as far as we can judge, throughout historical time. What tremendous play of thermal forces is thus argued for the body of the sun!

Direct Evidence of Activity. But we are not confined to indirect argument for proof of the mighty activity at play within the solar boundaries. Sun spots and solar eclipses both afford us direct and

observational proof. By whatever theory sun spots be explained, they are surely to be regarded as solar disturbances of vast extent. The very fact that they are visible from our distance implies that they affect vast areas. Over and over again they reach a diameter of eight thousand miles, large enough, therefore, to engulf the earth. At times the dark area extends one-eighth way across the sun's disk, betokening a diameter of a hundred thousand miles.

Moreover, these solar eruptions, tornadoes, or whatever else they be, are far from being infrequent in occurrence. There are years, it is true, when they are at a minimum and but few will be seen. But in maximum years hardly a day passes without the appearance of some sun spot, and on many days two, three, or more can be counted.

Without committing ourselves to any particular theory of the origin of these phenomena, we are yet constrained to admit that they denote solar activity carried on on a stupendous scale. For the sun spots are not stationary or tranquil. They break forth suddenly, enlarge to dimensions more than terrestrial, combine or divide, change shape and form and disappear, all in a few days' or weeks' time. We have to strain our imaginations to fancy the huge quantities of matter thus set in motion and the rapid velocity their particles attain.

Solar Eclipses. Of a piece with sun spots are the phenomena witnessed on the occasion of a total solar eclipse. When the sun's luminous disk is just covered by the interposition of the moon and thus hidden from our view, there appear outside the rim of the eclipsed body two circles of light which transform the eclipse into a spectacle of great beauty.

The inner circle or ring is called the chromosphere or sphere of color, taking its name from the brilliant crimson or scarlet light with which it is suffused. The outer is called the corona or crown. Pearly in color, it is a reminder of the nimbus or halo with which the heads of saints are encircled in Catholic works of art. Of high esthetic interest are these two envelopes of color, the one rich and gorgeous, the other delicate and elusive, appearing at the sun's margin on the exceptional occasion of a total eclipse.

The Chromosphere. But they are of astronomic interest as well, for they supply new and independent evidence of the sun's activity. From out the chromosphere, itself of medium thickness, shoot forth great flames of the same scarlet or crimson color to a height of tens of thousands of miles. Just as tongues of flame mount up from furnace fires to the tops of tall chimneys and appear surmounting them, so from the chromosphere arise these solar tongues of fire similar in kind but by comparison gigantic in reach and extent. After reading of these huge projections of colored fire of changing form and size, who can doubt that powerful volcanic forces are at work in the sun, that some mighty Vulcan there keeps his forge, the source of the energy which these columns make manifest?

The Corona. In the corona, too, the sun's outermost appendage, are signs of activity and change. In no two eclipses is the corona quite the same. Its boundaries vary and with them its average depth. Now the halo is of wide circumference, again it has shrunk to a comparatively narrow circle of pearl-colored light. At times there radiate from it far-reaching streamers stretching many millions of miles.

The detailed phenomena of the corona are naturally most elusive, for this envelope is composed of the lightest and rarest of gases. It is like the upper regions of the earth's atmosphere, the theatre by the way of the not dissimilar phenomena of the northern lights. But the corona's continual changes and its wide-extending streamers are signs of restlessness and of the eager play of physical agencies pursued on a scale to which the earth offers no parallel.

The Application of These Scientific Facts. Thus the sun itself tells the story of its own intrinsic activity. Through sun spots and eclipses it furnishes internal evidence that it is veritably a globe of fire, penetrated through and through with heat no solid substance could withstand, still less any living organism could for an instant endure. No plant or animal could survive for the fraction of a minute transported to the sun. Its extreme heat would be fatal to the stoutest organism. How wonderful it is that the sun, thus pitiless of life at its own surface, should be designed and adapted to foster and maintain life in happiest conditions at the surface of the earth! How wonderful is nature even in its antinomies!

Of itself destructive and overpowering, the sun's energy is so tempered by the time it reaches the earth that it lights without blinding, heats without consuming, and makes for the health and growth of the countless vital organisms that people the earth. Can chance or blind force account for such a benign dispensation? As well say that blind chance could have checked and harnessed the wild torrential forces of Niagara and bent them, as they have now been bent, to the service of man.

CHAPTER VIII.

HABITABILITY OF THE PLANETS.

We have seen that there are excellent and convincing reasons for believing that the sun is quite unsuited to be the residence of living beings. The same can be affirmed with equal certainty of the fixed stars, which, it will be observed, constitute an overwhelming majority of the visible heavenly bodies. Their likeness of nature to the sun both chemical and physical has been well established in modern times, and the conclusion is therefore forced upon us that they cannot be the abodes of life.

The writer wishes that something equally positive on one side or the other could be affirmed respecting the habitability of the planets, the bodies which make up the second grand division of the celestial system. But it is a subject in which categorical assertions whether affirmative or negative appear to outstrip the evidence. Nevertheless, whatever may be the hope or despair of attaining definite results, the problem is surely worthy of consideration, if for no other reason than that it continues to engage the thoughts of some of our best workers in the field of astronomical science.

Preliminary Remarks. At the very outset, distinction ought carefully to be made between the two

separate though allied questions of the habitability of the planets and their actual habitation. It is one thing to ask if the planets are suited to be the abode of life, it is quite another to ask if they are actually inhabited. There may be valid reasons for believing that the planets are suited to contain living occupants, but to infer therefrom that they actually contain living species would be illogical and, in the absence of pertinent evidence, gratuitous.

This division of the problem into two parts being premised, it is plain that the first offers more hope of solution than the second. The planets are not so distant from us but that we can learn much about their physical constitution and hence their aptness for containing living forms. On the other hand, they are quite too distant to bring such living forms, individually at least, within the scope of our vision even when aided by the most powerful telescopes. At the most we can expect only indirect evidence of the actual occurrence of life in other worlds than ours.

GENERAL THEORIES.

Advocates of Habitability. It is frankly to be admitted that a goodly array of names could be quoted in favor of the belief that other worlds than our earth are fit for habitation. As we should expect, these names belong almost entirely to the last three centuries, starting from the period of the establishment of the heliocentric theory by Copernicus.

The degradation of the earth to an inferior rôle in the drama of cosmic activity and the knowledge of its inferior size, led many to conclude that it was highly

improbable that our planet alone could be the habitat of living species. It was not unnatural that with their larger outlook on space the astronomers of the seventeenth century should conceive as by a first impulse the thought that there might be a plurality of inhabited worlds. From this century, therefore, we find quoted as defenders of the theory such respectable names as Tycho Brahe and Kepler, Newton and Bentley.

Evolution Theories. More recently other scientific hypotheses, less certain though they are than the Copernican, have strengthened in the minds of many scholars the presumption that life occurs in distant and remote parts of space. The Nebular Hypothesis of Kant and Laplace, originating in the latter half of the eighteenth century, pictures the earth as having evolved only in comparatively recent times from a primitive nebula, which was perforce destitute of life. Men would naturally inquire, then, if during the long centuries that the earth was being moulded there could not have existed life on other globes which were in a more finished state. For in the absence of this assumed fact, there must have been an initial period of untold length in which the entire universe was utterly devoid of corporeal life.

Influenced by such considerations, a very large number of astronomers of the early nineteenth century enrolled themselves on the side of what we may call the habitation theory. The list includes such representative astronomers as Laplace, the Herschels, father and son, Chalmers, Arago, Brewster, and Mitchell, the last being the founder of the first observatory in the United States.

Organic Evolution. Finally, the theory of organic evolution especially when pushed to the extremes given it by the ultra-Darwinians, is for its advocates absolutely convincing of the possibility and probability of the presence on other globes of living occupants. For extreme evolution reduces to the vanishing point the distinction between life and the non-living, and finds throughout all nature the essential prerequisites for the genesis of living forms.

It occasions no surprise, then, to find Haeckel and all others of the ultra-Darwinian school on the side of the habitation theory. On worthier grounds as we esteem them, other recent scientists, as Proctor, Flammarion, and Percival Lowell, have expressed their conviction that other bodies in the universe besides the earth have been favored with the honor of containing living residents.

A Preliminary Answer. Putting aside for the present the opinions of the trio just mentioned, we must take exception to the general line of argument that influenced all the earlier advocates of the habitation theory. If other worlds are not inhabited, asked they, what is then the purpose of their existence? Are they not as so many wastes and desert lands of no conceivable utility? And in the primeval period before the earth was formed, if the whole cosmos was without life, what useful purpose did it subserve? The argument implies that the world can have no other adequate purpose than to support life, that in its every period and in every considerable portion of its space there should exist living forms to which the merely material elements shall minister. But this claim while specious is gratuitous. Besides the

gratification of living creatures the world may have other purposes only partly comprehended by us. To give external glory to the Creator through the material manifestation of His power and intelligence, formed a sufficient purpose for the universe even in the first stages of its existence.

An Ultimate Purpose. Ultimately one of its purposes was, as the facts show, to minister to the needs of living beings and especially of man. Wide as space is, there is no part of it that does not make fuller the life of man. The most distant worlds engage his thought and compel his admiration. The distant past with its primeval chaos evolving into order and harmony, challenges his best powers of thought to unlock the hidden processes of the world's development and enlarges incalculably the purview of man's mental life. Sufficient purpose, then, there may be in remote worlds and remote eras even if destitute of life. As well doubt this as deny that the desert lands of Arizona or the Sahara or of the polar regions retain yet a sufficient purpose.

In any case, this argument of purpose is in great measure contradicted by the facts. For all the fixed stars, numbering tens of millions, are physically of the same order as the sun, all of them globes of fire and none of them, therefore, suited to be the dwelling-place of life. Here, then, are fifty million created globes which according to the proposed argument would have no sufficient reason for existence and yet which actually exist.

A Second Speculation. The problem of habitability becomes more difficult, however, when narrowed down to the planets. For here we are dealing with

bodies whose general nature assimilates them to the earth. They like the earth are, for the most part, firm and solid spheres, luminous only because of the sunlight they reflect and not in virtue of their own fiery incandescence. One's first impulse is to conclude that in view of the earth's well-known fitness for habitation, all its sister spheres, the planets, must be habitable also. Many a tyro in astronomy believes, undoubtedly, that the planets as a class are fitted to become the abodes of life.

But here again the argument runs too fast. With maturer knowledge the tyro will learn to halt before such sweeping generalizations. A fuller science will bid him subject to tests the individuals of the group, to learn if this planet here and that there fulfill the conditions required of them as habitable bodies. The outcome of his inquiry will be to glean that few of the planets if any are like the earth in its aptness to engender and maintain organic life. He will then reconstruct his theory, and cease to assign habitability as a necessary attribute of the members of the planetary system.

SPECIFIC REQUIREMENTS.

Conditions Needed for Life. There is a branch of knowledge whose special province is the living world, the science of biology. To it must the astronomer turn for the preliminary data needed in the solution of his present problem. From the biologist shall he learn the necessary material prerequisities of organic life.

Opening a standard text-book of biology, we find that for corporeal life there are demanded, first of all,

certain definite chemical elements. Carbon, oxygen, hydrogen, and nitrogen are substances so urgently required that throughout the whole range of the plant and animal kingdoms there is not a single species or form without them.

Let it be admitted at once that this first required condition is fulfilled by all the planets. As has already been noted, nature throughout her length and breadth has apparently made use of the same constituent materials for the construction of all her unit spheres, suns and planets alike. There is excellent reason to believe that any one of the planets chosen at haphazard, whether Jupiter, Venus, or any other, would reveal within its mass the raw material needed to form living protoplasm.

A Proper Atmosphere. There is need further of a proper atmosphere or gaseous envelope, on which plants and animals may draw for their subsistence. All living forms breathe in one manner or another. From the atmosphere plants take the carbonic acid gas that shall be converted into the carbon of their woody fibre. At the same moment animals extract from the air the oxygen so abundantly needed for the refreshment of their blood and tissues. Without a medium containing carbonic acid gas no plant life could exist; and no animal life without an added admixture of oxygen.

Failures Under This Requirement. It is certainly to be accentuated that the vast majority of the components of the solar system fail to meet successfully this second test. Indeed none of them meet it except the eight greater or major planets. The satellites or secondary planets, over twenty in number, are all too

feeble gravitationally to retain at their surface a proper atmosphere. To them must also be added as similarly restricted the whole group of minor planets or asteroids, a force of five hundred diminutive bodies occupying the zone between Mars and Jupiter.

True planets all of these are whatever be their distinguishing names. For they are solidified bodies shining by reflected light. Yet no one of them is enveloped in an atmosphere suited to the maintenance of life. The absence of all trace of atmosphere from the surface of the moon has long been a well-established fact of observational astronomy. And the moon is typical of the entire group above enumerated.

The writer is not unaware of Wm. Pickering's recent contention that the moon shows certain signs of the presence of vegetative growth. But the theory seems to rest, with due respect be it said, on slight and insufficient evidence, and has thus far failed of acceptance as an accredited fact.

Aqueous Element Needed. A third and one of the most imperative of all requirements for habitability is the provision of water at least in the form of humidity or moisture. The most indispensable requirements of living nature are the things which on this earth of ours have providentially been made the cheapest, a fertile soil, air and water. The last of these is so large and so necessary an element in all living protoplasm that without it life would be impossible.

That all the greater planets save one fulfill this requisite of a competent water supply, is within the bounds of likelihood. The probable exception is Mercury, exceeding but little the moon in magnitude and hence to be esteemed like the latter in its physical

conditions. On the moon's surface there is now no sign of change betokening the present erosive action of aqueous agencies. What were formerly called the seas or oceans of the moon are now believed to be great arid plains, of perhaps darker-colored rock than the rest or lying so flat and low that they receive less of the sun's illumination.

It may well be that as with the moon so with Mercury its original covering of water has evaporated into space, leaving the planet in each case a barren and lifeless waste. But the case of Mercury is exceptional. The superior magnitude of the other chief planets seems to preclude the chance that they have lost entirely the oceans and rivers and lakes with which they were originally engirdled.

TEMPERATURE TEST.

Life-Sustaining Temperatures. Finally, temperature or degree of heat has, according to all biologists, a most important bearing on the maintenance of life. There is a normal or middle temperature at which life flourishes best, exhibiting then its richest fertility. There are extremes of heat and cold no organism can withstand. The range varies indeed with different species, so much so that it is impossible to give figures that will apply to all alike. For man the optimum or ideal temperature is not far from 65° F., as our own experience tells us, and as the thermometer scale records.

To the temperate zone of the earth drift naturally all the dominant races of men because there ideal climatic conditions are so nearly realized. Indeed if

a calculation be made for all the geographical zones through all the seasons, the average warmth is found to be, according to Percival Lowell's latest book, in the neighborhood of 60°. So well suited is our planet to be the dwelling-place of man.

Other Forms of Life. For other species the average optimum temperature is given by biologists as a little above 90°. A sustained ascent to 122° is fatal to all species in the adult stage and descent to 32° is fatal to many. The germs or seeds of life, to be sure, can transcend these limits with safety, but it should be remembered that they are the products of life rather than its origins, and it still remains exceedingly doubtful if life could start into being outside the range given above. Moreover, even germs succumb to still higher or lower temperatures, as is evidenced in our modern practices of sterilization and refrigeration.

Further, relation between thermal conditions and a competent water supply deserves to be emphasized. Lowered to the state of frost and ice, or raised to the condition of steam, water would be unserviceable as a medium for life. A planet, then, whose constant temperature is either below 32° F., the freezing point of water, or above 212°, its boiling point, could not be admitted to be a fitting habitat for organized living beings.

Outer Group of Planets. It remains to apply this temperature test to the seven major planets, our present subject of study. How many of them fall before it, is matter for surprise. Astonishment begins when examination is made of the outer group of planets, comprising Jupiter, Saturn, Uranus and Neptune. These are the giants of the planetary

system, the least of them thirty-two thousand miles in diameter, and the greatest of them, Jupiter, almost ninety thousand.

They have their own independent glories, each of them endowed with special features of esthetic and astronomic interest. But not one of them could afford a foothold for living beings. Their heat is too intense. That we do not know their exact degree of surface temperature is of small account. We know enough to affirm that it is prohibitive.

Their Semi-Molten State. Their low specific gravity mathematically ascertained tells plainly the story of their physical condition. Their density averages one-fourth, or even less, that of the earth. Rock for rock, their constituent parts are expanded to four times the volume of the corresponding constituents of the earth. Excessive heat alone can account for such expansion.

Hence it is that all astronomers agree that these four planets are still in a semi-molten condition, not yet sufficiently cooled down from their primeval igneous state to have acquired the form and density of rigid solids. Miss Clerke has described Jupiter as a fluid globe, a semi-sun, showing no trace of a solid surface. Whence also Sir Rober Ball justly concludes, "I see no likelihood that Jupiter can be the home of any life whatever." Jupiter may fairly be taken as typical of all the components of the outer group. On no one of them would organic life have better chance of survival than in the crater of a lava-belching volcano.

The Inner Group. Of the inner assemblage, again of four components, Mercury is the first in order of

distance from the sun. The paucity of its atmosphere and its lack of water in the liquid form would seem to preclude the possibility of this planet's being inhabited.

If Mercury rotates so slowly as to keep one hemisphere turned always towards the sun, a fact which Miss Clerke accepts as probable, then on neither of its sides could fluid water be found. On the one hemisphere, that of perpetual winter and night, it would be transformed into solid ice; on the other, that of everlasting summer and sunlight, into the state of vaporous steam. On this basis Miss Clerke has seen fit to write that "Mercury is, according to our ideas, totally unfitted to be the abode of organic life."

The Second Planet. With Mercury is probably to be associated Venus, though it must be admitted in fairness that here the fact of slow rotation is less surely ascertained. With proper caution Miss Clerke couples together these kindred planets, saying: "With due reserve it may be added that Mercury and Venus have thus apparently been rendered unfit to be the abode of highly developed organisms."

Apart from all theory and mere probability, there stands the certain fact of the proximity of these two planets to the sun. On them descends a far larger proportion of solar energy than the equable amount that our planet receives. On Mercury the solar rays would beat down six times more fiercely than on the earth, an excess that would surely be destructive of life. Even Venus' share in the solar radiance is double that of the earth, begetting an increase of temperature which, theoretically at least, would make all life impossible.

The Planet Mars. There remains, then, but one globe of all that constitute the solar system, about which the question of habitability can be mooted with profit, in the sense of hope of an affirmative result. This is the planet Mars, one of our nearest neighbors in space, and of all the major planets the most favorably situated for observation. Its case is of such present interest that it deserves to be studied separately and in some detail.

Let it be conceded from now that Mars presents richer signs than any other planet of the power to support life in some of its simpler forms. This is far from conceding, however, that there is proof that it could support human life or any vital form akin to it. To Mars, as well as to all other worlds within our ken, applies the stricture of Sir Robert Ball, "Probably man could not exist for five minutes in any other planet or body of the universe, nor any being nearly resembling man."

The Earth's Ascendancy. The net result of our inquiry thus far has been to learn that habitability or the power of a created globe to support life, so far from being a common thing in nature, is a decidedly rare phenomenon. The power may not be quite exclusive to the earth, but within the solar system at any rate it is almost so. And as far as bears on human life, the earth's proud prerogative seems to be absolutely unique and unshared by any other body. Thus the earth, displaced from its pre-eminence of position in space by the establishment of the Copernican theory, retains still its pre-eminence of dignity and importance as being the only residence of life, at least in its highest and worthiest forms.

CHAPTER IX.

THE PLANET MARS.

The discussion of the habitability of other worlds reaches its climax in the planet Mars. All other heavenly bodies within our observation are now to be regarded as eliminated, if not indubitably from the category of habitable worlds, at least from the field of profitable discussion. Before one or another test have fallen whole groups that were formerly deemed likely subjects of inquiry, the fixed stars, the satellites, the asteroids, and finally the major planets, with the single possible exception of Mars. Whatever our preconceptions may have led us to expect, all the evidence is against the likelihood that any one of these numerous bodies is possessed of living occupants.

But the case of Mars is not to be so readily dismissed. Indeed, it remains for us to see if it is to be dismissed at all. For many decades past, books of astronomy have given to Mars the distinction of being more nearly like the earth than any other celestial object and more worthy to be credited with the character of habitability. Even half a century ago speculation was rife as to what might be the nature of the creatures that people the ruddy planet.

The Canals of Mars. It is now a little more than thirty years since Schiaparelli, an Italian astronomer

of note, announced his discovery of certain markings on Mars, to which he gave the name of canals. Canali he called them in the Italian tongue, the name meaning waterways of any sort whatever, whether artificial or natural. But translated into our vernacular, the term conveyed at once the impression of artificial channels designed and executed by intelligent agents. Here, then, according to the world's misconception of Schiaparelli's meaning, were clear signs of intelligent life on Mars.

Careful astronomers pointed out that these lines crossing the planet's disk could not possibly represent water-courses artificially constructed. For the least of them, it was urged, must be fifty miles in width to be visible in our telescopes, and it was preposterous to suppose that intelligent beings had gone into the business of canal construction on so enormous and futile a scale.

Prof. Lowell's Findings. Even the recent computations of Percival Lowell, to the effect that some of the canals are as low as ten miles in width, do not save the situation as bearing on the artificiality of these reputed waterways. For the nation that would set to work to make an aqueduct ten miles broad would appear as foolish in the world's eyes as the ancient projectors of the tower of Babel.

Not that Lowell himself judges these dark bands to be aqueducts. Be it added at once that nothing is more foreign to his thought. Some fifteen years ago he conceived a new theory of the so-called canals, which, besides being of itself attractive, removes at once the difficulty of the canals' exorbitant width.

His Theory. His theory of these markings is that they are broad tracts of vegetative growth, forests or fields of grain, which flank central waterways of moderate width, the latter, however, being of artificial origin. The verdure, which he supposes the dark lines to signify, requires water for its sustenance. It will grow and abound only along the banks of rivers. But on Mars it grows so regularly, along definite lines measuring hundreds of miles in length and running always straight as a die, as to connote and demand artificial control of the streams which nourish it.

The theory has been so insistently urged by Lowell that it has forced itself on popular and scientific attention alike. And it is the commonest of experiences nowadays to read in journals of all sorts and qualities, references to the Martian inhabitants, always, of course, represented as highly intelligent and man-like, for this is the only sort of inhabitants that most persons care anything about.

It seems a pity to be compelled to subject so enticing a theory to the cold analysis of scientific scrutiny. Imagination has its part to play, undoubtedly, in the discernment of truth and is not to be esteemed the least of our faculties. Its worth ceases, however, when its use is misapplied.

Facts About Mars. The planet which takes its name from the Greek god of war, is unquestionably more like the earth than any other globe we know. It is somewhat less than the earth in size, its volume one-seventh and its mass one-ninth the latter's, but as cosmic bodies are reckoned, this disproportion is not large. It has its day and night, differing in

length from ours only by minutes and not by hours. It has its seasons and its year, each double the earth's in duration.

As a consequence of its somewhat greater distance from the sun it receives but one-half as much of solar heat and energy. Theoretically this would reduce its temperature below the point at which life could subsist. But there may be compensating circumstances that modify the theoretical calculation, and as a matter of fact the evidence of melting ice and running water on Mars argues a higher temperature and one agreeable to living forms. In size, seasons, alternation of day and night, and degree of heat, it is not so disparate from the earth but that it could safely be imagined the abode of life.

Other Signs of Habitability. An earlier study taught us the transcendent importance for life of an atmosphere and water. There are evidences of both on Mars. Its atmosphere, as scientists agree, may well combine the essential ingredients of ours. reduced ninefold, however, in density. Water is denoted by the white polar caps, which melt away as summer advances, only to form anew in the succeeding winter. No longer, as formerly, is the provision of water esteemed to approach the earth's in magnitude. The polar fields of ice and snow, extensive but shallow, are the planet's only reservoir and means of irrigation.

A fair review of these facts and conditions suffices to persuade us that Mars is in all likelihood habitable for some forms of life. Here at last we have met with the conditions we were seeking. This planet is the only body in the universe outside the earth of which

we have any positive or goodly reason to affirm fitness for habitation.

Does Habitation Follow? To jump from this, however, to the conclusion that it must be inhabited is an offence against good logic. The extreme fertility of the earth misleads us into believing that all soil which can will teem with life. But the fertility and after-growth of life is the easiest thing about it to explain. The hardest is to say how and where it got its start. Mere inert matter never produces it, so says all the evidence, and so report the scientists. Unless God by a special creative act puts life upon a planet, we believe that it will not there be found.

Lowell believes otherwise. He clings tenaciously to the theory of spontaneous generation, a doctrine we had supposed pretty well abandoned by prudent scholars. He holds that a planet, properly conditioned, will infallibly produce life by its very nature and as an inevitable incident in its development. Were life of a piece with volcanic activity, we could agree with him. But persuaded as we are that life is a unique, distinct, mysterious phenomenon, inexplicable on any mere mechanical or physical theory, we cannot agree that a planet as such is bound some day in its history to beget living forms.

Physical conditions alone will not suffice. A little reflection will remind us that the abundant living things of earth come not from the latter as a mere planet careering through space, nor from its water and atmosphere, its carbon, oxygen and the like, necessary as are all these, but always and solely from pre-existing life. And the beginnings of terrestrial

life we believe with good reason to have come from a special creative act of God.

Evidences of Habitation. But will not God have created life on Mars? Of his purpose we cannot know. But perhaps there is actual evidence at hand. Lowell says there is. He finds evidence of life in two forms, of vegetative growth along the canals and at their junctions, and of intelligent life in the systematic planning of the canal system.

Possibly the first holds; the dark lines may represent vegetation. He has studied them and their changes more than any other man and is most competent, perhaps, to make an inference. He has yet to explain, nevertheless, how with such an impoverished water supply three-eighths of the planet's surface can still be the seat of vegetation. For other than as vegetation areas, there is given in his book no explanation of the great dark spaces which cover almost half the surface. And if these dark spaces stand not for vegetation, why any more the dark narrow lines which are of the same hue?

Activity Intelligent and Unintelligent. But vegetative life conceded, issue may fairly be taken with Mr. Lowell's contention that on Mars exists a higher order of life in the form of intelligent corporeal beings. His argument rests on the perfect regularity of the so-called canals. These run for hundreds and even thousands of miles along perfectly straight lines. No natural force, he claims, can account for such directness. The only hypothesis that will explain them adequately is that they are irrigation tracts outlined and executed by intelligent beings, who take this means of spreading the sparse waters of

the melting polar caps over an otherwise arid and desert globe.

Delightfully fanciful as is this hypothesis, the objections to it are numerous and considerable. We are asked to believe that man or his Martian counterpart has covered the whole surface of Mars with a most intricate and complicated network of waterways and sluices. The similar irrigation devices on the earth are to be numbered in units; on Mars they number hundreds. Over four hundred have thus far been counted. Truly the Martian engineers have been busy with the labor of canal construction!

Formidable Objections. The least of the discovered canals measures two hundred fifty miles in length, the distance separating Boston and New York. The greatest extends four thousand miles, and would therefore traverse our continent from ocean to ocean. With us it is no easy feat of civil engineering to carry a city's water supply from a distance of fifty miles.

The Martian canals run straight as a ruler, with never a turn to right or left. There is never a detour to this side or that for the finding of more workable soil or rock, or for the rounding of the Martian hills which Lowell concedes to exist. Where on this earth could be found an aqueduct or railway or street or any other artificial road thus pursuing its course evenly without detour for ten miles, not to say four thousand? The canals are too perfect to be of human origin. Four hundred thousand miles of aqueducts, built each of them without a turn, this is, we opine, too much for human credulity.

It is scarcely necessary to advert to other facts which Lowell leaves unexplained. The doubling of the

canals, a phenomenon first perceived by Schiaparelli, occurs, according to Lowell's estimate, in almost one-eight of the total number. It is a singular fact and would seem to be an unwise duplication that so many conduits should have been laid side by side in mathematically parallel lines. Of this strange phenomenon Lowell's latest and maturest book does not venture to offer an explanation. A further singularity, also left unsolved, is the continuance of the canals not merely over parched deserts, but through the dark areas which are assumed to be regions still supplied with vegetative life.

Silence of Astronomers. Creditable as has been Mr. Lowell's exploration of the ruddy planet, unequalled indeed by that of any other observer, we know of no astronomer of repute and distinction who agrees with the most important of his inferences. Schiaparelli was attracted by the vegetation theory as an explanation of the canals. But he is not quoted as having acknowledged their artificial character. Wm. Pickering of Harvard is also disposed to accept the dark spaces and lines on Mars as indicative of plant life. But he believes the lines followed by this vegetation to be natural clefts in the Martian surface, like those of which our moon offers many instances. For the rest, who among astronomers of name and note can be quoted on Lowell's side?

Earth Without a Rival. The criticism we have made is not the fruit of bias or prejudgment. It is consistent with and accompanied by a profound appreciation of Lowell's astronomical labors, unparalleled in this particular field. But his interpretation of the facts amassed taxes our faith too sorely.

As we interpret the evidence, it avails only to prove the possibility of some low orders of life on Mars. It falls far short of witnessing to human occupants. Sweeping the universe with our mental vision, it seems to us not yet disproved that in the mysterious plan of Providence the earth alone has been designed and framed to be the suitable residence of intelligent corporeal beings.

CHAPTER X.

THE SIDEREAL WORLD.

Hitherto our considerations have been limited for the most part to the members of the solar system, comprising the sun, the planets, and the satellites. There are excellent reasons for extending now the range of our investigations by delving a little into the larger subject of sidereal astronomy, the study of the fixed stars.

To the Catholic, believing firmly in the fact of the world's creation, there is no body in the universe from the least to the greatest, from the nearest to the most remote, that is altogether without interest. All are the products of God's handiwork, all have felt the impress of His creative wisdom and love. We cannot imagine, with reverence be it said, that the Godhead is indifferent to any single object which He has called into being. No more can they who believe in Him, remain indifferent or be content to abide in ignorance.

Astronomy Religious and Irreligious. It is time, moreover, to rescue the science of the heavens from the sad condition into which with too many it has fallen in these later days. Too long has the study of the stars been in many quarters divorced from the study of religion. Many an astronomical manual could be named which from cover to cover contains

no mention of the Deity. How unlike the sacred books of the Hebrews, which whatever their astronomical defects, never ceased in prose and verse, in hymn and parable, to ascend from creature to Creator, on every page and in every canto rendering praise and glory to the acknowledged Author of the universe!

To restore astronomy to its former more honorable rôle is indeed one of the purposes of these essays. They are intended, as far as they may, to annul the long-standing divorce between the astral and the divine science. They start from the conviction that astronomy, properly pursued, is calculated of itself and in all its parts not only to refine the mind, but to exalt our concept of the Godhead. For the invisible things of God, His eternal power and divinity, are known from the visible things which He has made. (Romans i, 20.)

Lessons of the Stars. Something of this mood must steal upon us whenever of an evening we lift up our gaze above the lowly earth and look aloft to the nocturnal sky studded with its myriads of stars. There they abide, those flashing diamond points of light, set against a dark unfathomable background. Nowhere in nature can be found a more perfect symbol of serenity and repose.

In its hour of disquietude or distress, the soul of man can find assuagement and tranquility in the contemplation of the heavens, with their spectacle of perpetual calm unbroken by the vicissitudes of earth and the tumult of warring passions. There is no tumult in the heavens, but all is steadfast calm, an image of the unaltered and unruffled peace that marks the life of the eternal God.

Symbols of Eternity. And in their own degree they image eternity as well. At times as we gaze upwards, there crosses our mind the thought that the same constellations which now look down on us have kept their faithful watch over all the multitudinous successive events of human history. They have seen dynasties and nations come and go. They have looked down at midnight on the pitched tents and sleeping camps of a Napoleon, a Charlemagne, a Caesar, an Alexander. Abraham, father of the faithful, watching his flocks by night, beheld on high the same canopy bedecked with the same star-groups that now with unaltered configurations look down upon us.

Go back as far as we may in human history, to its cradling in the Far East, already in that distant past these self-same stars were at their posts, bright, serene, and fresh as now. Their youth and vigor is more than that of the eagle, it remains unimpaired throughout all the eras of which man has record.

From the mere viewpoint of time, how insignificant are our lives compared with their existences! Aged to the degree of centuries upon centuries, and yet youthful with undiminished lustre, they speak to the ear attuned to catch their voice the lesson of eternity. More vividly than any other spectacle in nature, they serve to symbolize the truth of God's eternity, without beginning or end, the same yesterday, today and forever.

SCIENCE OF THE STARS.

Their Scientific Study. To turn from such contemplation to analysis, seems like breaking a spell or like descending from the heights. It is as it were deserting

poetry for prose, to abandon the first intuitive spirit of awe which the nocturnal heavens create and to begin to measure with compass and rule the distances and magnitudes of the stars.

But, rightly executed, the change needs involve no descent. In place of lessening our sense of mystery and awe, the study has power to deepen it. For a fuller knowledge of celestial measurements will inform us of the immensity of space and the colossal scale on which the world has been constructed.

Star Distances. How far from us are those gleaming lights? They seem our near neighbors, no more distant than the clouds. It is our sky they ornament, the firmament whose distance seems measurable in hundreds of yards rather than in miles. This firmament is the vaulted ceiling of a great natural hall, whose floor is the earth's level with its limiting horizon, and in which there seems established a perfect proportion of height and breadth.

But were the stars only a few hundred yards away, they would drop to the earth by sheer force of gravity. They are far enough off at least to escape the visible effect of this attracting force. They are farther from us than moon and sun and planets. For these pass in front of them at times and shut them from view. Like distant lights at sea the stars remain motionless while the nearer beacons, sun, moon, and planets, move in and out among them. And yet these nearer beacons are themselves millions of miles away.

So far beyond lie the stars that our largest telescopes leave them unmagnified. Twenty-five trillions of miles, such has been calculated to be the distance of

the nearest of the stars. By such unimaginable and almost incredible spaces are the stellar bodies separated.

Star Sizes. If we ask further of what magnitude are the stars, again we find that our senses or the inferences we draw therefrom deceive us utterly. The stars appear as so many electric lamps or even candle-lights, almost without dimension or extension. But were they no more, they could not have continued to blaze throughout the long ages of history. Long ago they would have burned to cinders, as do now the meteors or shooting-stars. And were they only such, they would not be viewable at all at their enormous distances. Light spreads as it goes, becoming ever weaker and fainter, till finally it disappears from sight. The amount of luminosity the stars still bring from their prohibitive distances tells the story of their unsuspected magnitude.

It is a certain fact that could the sun be removed to the distance of twenty-five trillions of miles, its luminosity would be so diminished that it would shine only as an ordinary star. The stars are suns, therefore, paralleling our solar orb in their immensity.

Star Magnitudes. By magnitude astronomers mean, not the volume of the stars, but their degree of brilliancy. The division of stars into classes according to magnitude is, of course, more or less arbitrary. Only twenty stars are rated of the first magnitude, ranging from Sirius the Dog-Star to Deneb in the Northern Cross. A dozen more of these bright orbs are visible in our northern latitudes, viz.: Capella, Arcturus, Vega, Rigel, Procyon, Betelgeux, Altair, Aldebaran, Fomalhaut, Antares, Pollux, Regulus, and Spica.

In the next class, the second magnitude stars, about sixty-five are placed. The number goes on increasing thus in fairly regular proportion till the sixth magnitude is reached, represented by some five thousand stars just at the limit of unaided vision. With the telescope much fainter objects can be made out, down to at least the fourteenth magnitude.

Number of the Stars. Again, we may be curious to know how numerous are the stars. The naked eye counts them by thousands, the telescope by millions. Recently the Abbé Moreux gave their number as 150,000,000. The estimate may be exaggerated, but it seems quite likely that when the international work of cataloguing the stars has been completed, a work in which the Papal Observatory at Rome with seventeen others is now engaged, the number will easily total 50,000,000. What an enormous army, not far below the total citizenship of these United States! And every individual of this host is a sun, a fiery world, a giant orb as we terrestrials measure size.

Relation With the Earth. Yet all these legions of independent worlds are somehow brought into relation with our diminutive earth. Whatever they be intrinsically and whatever their other purposes in the design of God, one purpose we know them to have, to relieve the emptiness and darkness of our firmament by studding it with innumerable gems of sparkling light. Worlds in themselves, they become so reduced in size by optical laws that they are transformed into jewels for the enrichment of our heavens. Covering heaven's canopy with pictures outlined in light, they engage and gratify our sense of the beautiful.

How well-nigh incomprehensible it is that those mighty stellar worlds should minister to our delight by supplementing the attractions of our petty earth! And yet it is right and just. For our faculties and qualities are all but infinitely superior to theirs. Their grandeur is merely material, ours is spiritual. The distances and magnitudes and numbers of the stars bow before the powers of him who can measure their courses, enjoy their splendor, and contemplate with understanding and admiration their wonderful design. If the stars symbolize God's eternal serenity, we have that within us which typifies the higher attributes of God's being, His divine powers of wisdom and knowledge and love.

MORE INTIMATE STUDY.

To learn anything in detail of objects as distant as the stars, would seem altogether beyond the bounds of reasonable expectation. A separation of trillions of miles without the possibility of nearer approach, must bring discouragement, one would think, to even the most ardent observer. Science, however, seems ignorant of the very word discouragement; and it has dared to face the apparently impossible task of exploring the farthest realms of space and penetrating their mystery.

Composition of the Stars. Until fifty years ago, it seemed impossible that we should ever learn aught of the internal make-up of the stars. But in that year was found a key to their composition in the establishment of the science of spectrum analysis. By the spectrum, as had been known from New-

ton's time, was meant the band of color into which light spreads out when passed through a transparent prism. It was now found that the spectrum varies according to the source of light, each of the chemical elements, as hydrogen, sodium, iron, and the rest, giving its own distinctive spectrum when rendered incandescent.

Here, then, was a means for sounding the nature of the stars, by analyzing the light they emit. Father Secchi, the celebrated Jesuit astronomer, was the first to apply the test in 1863, subjecting to it as many as four thousand stars, or more than half of all that are visible to the naked eye. He arranged them in four classes, according to their predominant colors and distinctive spectra. Bluish-white stars, as Sirius, were found to be rich in hydrogen. Yellow stars, as Capella and our Sun, possessed sodium in large quantities. Red stars as Antares, and ruby stars of fainter lustre, contained other components.

One interesting fruit of this study has been to learn that in those exceedingly remote worlds there are no elements other than what the earth contains. In the stars, however, the elements are not compounded as on the earth into water, granite, and the like, but are kept by the extreme heat of fusion in their original state of chemical simplicity. In complexity and variety and adornment, the stars, notwithstanding their splendor, are far inferior to the earth.

Temporary Stars. The most peculiar and remarkable of all stellar phenomena is the sudden flashing forth of a star in a part of the sky where none had

appeared before. The strangeness of such a spectacle will be the better appreciated if we recall the vastness of size attributed to the stars. That a body of the proportions of the sun should appear in space suddenly and without warning and take its place for a few weeks or months in some fixed constellation and then fade gradually into invisibility, is certainly remarkable.

But the fact has been observed so often that it cannot be gainsaid. It was the sudden appearance of such an orb of fire in the sixteenth century that excited the attention of Tycho Brahe and started him on his life-work as an astronomer. Since then, fifteen others have appeared at different periods, an average of five for each century. The latest was the New Star in Perseus, which appearing early in the year 1901 and mounting to the first magnitude, changed temporarily the map of the constellation.

Proffered Explanations. No explanation of this startling phenomenon can be regarded as altogether satisfactory. It has been supposed by some that the outbreak of light is due to the impact of one great globe on another with the accompanying development of enormous heat. This collision hypothesis seems to be at the basis of Mr. Percival Lowell's recent suggestion, that the earth will one day meet its end by colliding with some foreign body.

A more likely explanation is that of a sudden tremendous explosion within the body of the star itself, accompanied by the release of subterranean fires and by other volcanic phenomena, continuing for several weeks or months and then slowly sub-

siding. This would seem to account more satisfactorily for the unexpected blazing forth of the New Stars. The occurrence, however, is so distant from us and withal so relatively infrequent that we can only speculate about its cause.

Variable Stars. Finally, there is an interesting class of stars, composed of those whose light waxes and wanes according to a periodic law. The first of them was noted by Fabricius at the end of the sixteenth century, and was given the appropriate designation of Mira or Wonderful. It changes regularly from the eighth to the second magnitude, in a period of eleven months. All that thus alter in brightness, albeit in unequal periods, are called Variable Stars.

A large number of these are now known to exist, thousands rather than hundreds. Not all of them are to be similarly explained. But the variability of many is almost certainly due to the interposition of a dark planet attendant on the star, crossing it at regular intervals and partially intercepting its light. The variable stars thus afford fair evidence that other stars besides our sun are accompanied by planets.

Recently Campbell of the Lick Observatory in California has secured spectroscopic evidence, also, of the presence of planets in some of the stellar systems, notably in the case of variable stars. Indeed, he has announced that there is positive reason to believe that one star out of every thirteen in the universe is accompanied by one or more planets. The sun, then, is far from being the only star attended by a planetary system.

Order of the Universe. Such are the main facts gleaned from a close and rigid scrutiny of the stars. Passed in review, they teach us that these mighty worlds are not scattered promiscuously through the universe but well and adequately spaced. Where crowding seems to occur, as in the Milky Way, it is merely the result of optical illusion. Astronomy further depicts them to us, not as flying wildly through space and thus endangering the existence of their companions, but kept apart and governed by some common law which reduces all their movements to harmony.

Of uniform structure are all these myriad spheres and of similar though not identical composition. Yet each is in its own way active, some guiding planets on their courses, some blazing betimes with unwonted light, but the vast majority flaming steadily and unceasingly, and remaining, therefore, constantly visible from our post of observation. Though all is not yet revealed, we know enough to affirm that in the sidereal world there prevail order and unity no less truly than in our own solar system.

CHAPTER XI.

HABITABILITY OF REMOTE PLANETS.

Probably the most interesting fact taught by sidereal astronomy is that besides the familiar planets of the solar system there exist in all likelihood numerous other planets, attendant on the several suns of nature, the fixed stars. The discovery of these new systems of ancillary bodies, may raise again in the minds of some the problem of the habitability of other worlds than ours. Curiosity respecting the possible intelligent occupants of other worlds is not to be allayed, we are well aware, by the brief exposition of adverse arguments presented in our earlier articles. Like Banquo's ghost, speculation on these matters will not down. It is bound to rise again.

New Field for Speculation. An advocate of habitability may not unjustly make the point that the more remote planets recently brought to light offer new ground for speculation. The arguments thus far presented, they will contend, by omitting the newly discovered planets, leave untouched a whole array of celestial bodies whose case is certainly worth considering. He, therefore, will petition that the case be reopened.

A pleader of this sort will not rest satisfied with the rôle in nature which we have presumed to accord to

the fixed stars. To constitute a celestial panorama for the delectation of us terrestrials, will impress him as an insufficient and unworthy destiny for this multitude of gigantic bodies. To toss off their purpose thus lightly, to assign them an office so mean and lowly, will appear to this advocate too great a depreciation of their rank and order.

A Possible Purpose. In the design of the Creator, he may urge, those massive fiery globes which we designate as stars, must have some nobler end than merely to form for us a celestial picture, and light up so dimly our earth on moonless nights. Have we not a key to that further and higher purpose in the demonstration of the planets by which they are accompanied?

Over these dependent bodies the stars will exercise an influence akin to that with which the sun sways the earth. Around each star planets will revolve in orderly orbits obedient to its gravitational impulse. Of this sort of control neither we nor the habitationists can possibly have doubt. Nor can we doubt that the stellar planets will be both illumined and heated by the radiant energy of the fire of the stars. Like our sun, the stars may rightly be assumed to play the part of light-giving and heat-supplying centres.

The Argument for Life. Why, then, may not the analogy be pursued, and the stars be construed as life-giving centres as well? If in so many regards their office is kindred to the sun's, why deny to them the further power of vivifying their planets literally, by maintaining and fostering therein forms of life such as our earth exhibits in such plentiful measure? Are not all the required conditions verified? Given

stable planets capable of affording a firm foothold for life and a nearby sun prolific of life-sustaining influence, is it not probable that life will arise and through the natural process of evolution mount on its upward course till there appear on these planets beings of as high a type as man?

The enthusiast for habitability will press the point by urging that he thus finds for the stars an adequate reason for existence, namely to promote life in the systems which they govern. And moreover he will plead very forcibly the extreme unlikelihood that our earth has been specially selected from so many million globes to be the sole and exclusive habitat of living beings.

Persuasiveness of the Argument. That this reasoning has some color of truth, is scarcely to be denied, and is indeed attested by facts. For it has secured a multitude of adherents, and multitudes do not follow error wantonly. The most important of the recent converts to the habitation theory is Simon Newcomb of Washington, the Nestor of American astronomers. His conversion at the eleventh hour is an affair of more than passing moment.

Comparison of this scientist's earlier and later pronouncements reveals a change of front respecting our present problem of the most remarkable kind. Many a passage could be quoted to show that the earlier Newcomb viewed with the most absolute scepticism all claims for the habitability of other worlds. But in Harper's Monthly for August, 1905, he appeared for the first time as an advocate, cautious if you will, but still a sympathetic exponent of the habitation theory.

A Remarkable Conversion. If his change of attitude is already remarkable, the sweeping character of his later conclusions is little short of amazing. He had just previously labelled the habitation of Mars "a pure supposition," and had confessed frankly to his perhaps disappointed readers that he knew no more of the possible inhabitants of Mars than they did, which was "nothing at all." But now there came to him a new light. And in the article of the year 1905, he no longer excluded "the probability that a vast number of worlds might be fitted for habitation." "All the analogies of nature lead us to believe" that if fitted they will be inhabited. "It is therefore perfectly reasonable to suppose that beings not only animated but endowed with reason inhabit countless worlds in space."

The present writer can hardly comprehend so astounding a reversal of thought. But it has undoubtedly been inspired in part by our newly acquired knowledge of planets, whose existence was not before suspected. And for its argumentative basis it must rest on some such line of reasoning as has been unfolded in the early part of this paper. To this argument, therefore, we should now give some attention.

Value of the Argument. Epitomized, the argument says that we must find if possible a worthy motive for the existence of the stars. A probable motive is that they are to serve their planets by fostering life therein. And thus are we saved the unnatural hypothesis of supposing the earth the only inhabited body in all space. To deny all force to this contention would be unreasonable as well as

disrespectful to the men of quality who have urged it. But the degree of its force may be questioned without the danger of such unpleasant consequences.

An obvious restriction on its value is that it is almost entirely speculative. It cannot be made to meet empirical tests. The newly-discovered planets are so extremely distant that we can have no hope either now or in the future of bringing them within the range of observational investigation. Neither the advocates nor the opponents of habitability can entertain the hope of obtaining a shred of positive pertinent evidence. And in a matter of this sort the burden of proof would seem to rest on those who take the positive side.

Worth of Speculation. It is not to be forgotten that in the past similar speculations have been indulged in, which are now completely discredited and relinquished. As before noted in these essays, the best of astronomers once thought that the sun and the stars were fit for habitation and therefore probably inhabited. The grounds of their belief were essentially no other than those at present alleged, a worthy purpose for these bodies and the reduction of the earth to its proper rank as a relatively insignificant part of the universe.

But when the day came that they were driven from this position by incontrovertible facts, these men or their successors, in perfectly good faith and guided by probability, transferred their speculations to the planets of the solar system. But even from this ground they were soon forced to retreat. Within the solar system their only present refuge lies in the planet Mars.

Weighing of Probabilities. The fate of these speculations of the past should teach us caution. But perhaps the present speculations, as those of Newcomb, have been more cautiously framed. In the study of nature we have often to depend on probabilities. And in mooted questions, wherein certainty is unattainable, it is the part of the prudent scholar to lean to the more probable side. The probability, however, must be genuine to justify his even qualified assent.

Is there this sort of probability for the claim that the remotest planets are inhabited? The claim rests on two grounds, that the stars being suns have power to sustain life, and that the earth cannot be alone in its possession of life.

The first reasoning is perceptibly weakened by the consideration developed in an earlier chapter that the sustenance of life is quite a different process from the first creation of life and is in comparison a power of infinitely inferior kind. The life-sustaining properties of the stars, therefore, can prove nothing for the habitation of their dependent bodies.

Singularity of the Earth. That the earth is alone inhabited, does seem at first unlikely. But nature is full of mysteries and this may be one of them. It seemed unlikely once that the other solar planets from Mercury to Neptune should remain unblessed with living inhabitants. But in their case, with one possible exception, the unlikely has now been found to be the true. What reason have we for supposing anything different for the stellar planets? Newcomb speaks of the analogies of nature, If analogy teaches anything in this matter, it is that uninhab-

ited globes are the rule, and an inhabited globe the rarest of exceptions.

It is the earth's singular conditions and not the mere fact of its being a planet, that adapt it so well to be the residence of life. It lies in the temperate zone of the solar system. Its nutrient materials, its varied topography, its changes from season to season, and even from day to night, all these special conditions favor the reposeful continuance of life and its countless species. Are there any other planets in all nature where the same happy conditions are realized? Who shall affirm this to be true or even probable?

The Criticism Applied. How extreme in the light of these considerations must now appear the statement of a grave astronomer, that "it is perfectly reasonable to suppose that beings not only animated but endowed with reason inhabit countless worlds in space"! Has not our grave astronomer been nodding? And may we not appeal from Newcomb dormitans to Newcomb vigilans? We venture the appeal and quote his earlier phrases which we beg even now to make our own, that the habitability of other worlds is "a pure supposition," and that "the only reason to believe in such inhabitants is the fact that our earth is inhabited."

CHAPTER XII.

THE BIBLE AND ASTRONOMY.

To the Catholic versed in astronomy there could scarcely be proposed a more inviting subject of inquiry than the relations between that science and the Holy Bible. Years of delightful study, on the one hand, have bred in him a genuine love for the science of the heavens. Years of religious habit, on the other, have taught him to cherish the Holy Book, as the ultimate fount of revealed truth. To search the Scriptures, then, for points of contact and, if it so chance, signs of agreement between the two revelations, the natural and the divine, will appeal to him as perhaps could no other task.

Two Recent Guides. To aid in this important study, there are fortunately at hand two excellent books of recent date dealing expressly with the astronomical references of the Bible. Schiaparelli, the discoverer of the Martian canals and the most renowned of recent Italian astronomers, has lately contributed to the literature of the subject a valuable work entitled "Astronomy in the Old Testament." And in 1908 there was issued a volume of somewhat wider scope, called "The Astronomy of the Bible," by Mr. E. W. Maunder, Fellow of the Royal Astronomical Society. The appearance of

such works from the pens of expert scientists is itself a tribute to the interest of our subject.

One can be sure of safe and reliable guidance in following either of these publications. They emanate from authorities at once competent and impartial, this twofold quality not being impaired by the additional grace of a becoming reverence for the Sacred Scriptures. We feel secure, therefore, in adopting them as our chief guides in the summary we now propose to give of the astronomical teachings of the Bible.

Teachings Respecting the Earth. Foremost among the principles of modern astronomical science is the now familiar truth that the earth is a body of spherical shape suspended in space. It would be unnatural to expect that the Hebrews could in their early period have become acquainted with this geographical fact. But it is interesting to learn that the Scriptures suggest no contradiction of the fact and even contain allusions quite in keeping with it.

There are several texts indicating that the ancient Hebrews viewed the earth as a mass set apart, limited in extent and surrounded on all sides by empty space. The Book of Ecclesiastes, for example, in its first chapter speaks of the sun as "rising and going down and returning to his place," words which clearly signify a complete daily circuit of the sun about the earth.

To the moon, also, according to Schiaparelli, a similar course was probably attributed. And in Judges, v, 20, there is a reference to the orbits of the stars. With this correct concept of an enclosed and limited earth, contrast the contemporary teaching of Xeno-

phanes, the Greek philosopher, who supposed that the earth was infinite in extent and as a consequence that each day's sun and moon and stars were new creations.

Here may be recalled also the remarkable passage in Job, xxvi, 7, where it is said that the Lord "stretcheth the north over the empty place and hangeth the earth upon nothing." We need not go so far as did Lord Bacon who discovered here a reference to the roundness of the earth. But there is certainly here the absolutely correct teaching that the earth remains hung in space without support. How this rises above the grotesque fancy of the ancient Hindus, who thought the earth supported by an elephant, the elephant by a tortoise, and the tortoise by a snake!

Character of the Heavens. The heavens above the earth, naturally our next object of interest, present to the glance the aspect of a solid blue vault or arch. But we know to-day that this appearance is merely an effect of optical illusion. For beyond the atmosphere there is for the most part only wide-stretching space. Some have imputed it as a fault to the Hebrews and as a sign of their ignorance in matters scientific, that in their Scriptures they often refer to the skies by the name firmament, a word betokening utmost firmness and solidity.

But it is interesting to learn that, in the opinion of at least a fair number of critical scholars, the Hebrews themselves never employed a word answering to our "firmament," and are, therefore, saved the dishonor, if such it be, of having conceived the sky as a rigidly solid vault. Before reaching us, the Hebrew Scriptures have passed through the hands

of Greek translators of the third century before Christ. These translators, consonantly with the Greek astronomy of the time, rendered the Hebrew names for heaven by firmament. The error of supposing the heavens solid as crystal was certainly an element in the ancient Greek philosophy. It is extremely doubtful if it formed a part of the natural philosophy of the Inspired Books.

Hebrew Names for Heaven. The Hebrews in their prose writings used two words for heaven, one meaning "expansion" and the other "uplifted." These are the designations which the Greeks mistranslated into firmament. Either of them would be accepted even in our day of scientific progress as fitting and appropriate. For the heavens are to all appearances stretched out from zenith to horizon and uplifted high above the earth.

In their poetical writings, indeed, the sacred writers often pictured the skv as a tapestry or curtain, or again as a pavilion or tent, as in Isaias xl, 22, "He spreadeth out the heavens as a tent to dwell in." But such terms are plainly figurative, and in keeping with the poetical character of the chapters in which they occur. Interpreted as metaphors, they allow us still to believe that the Hebrews thought of the heavens much as we do today, not as a solid vault, but as an empty space spread out above the earth and lifted up on high.

The "Windows of Heaven." Some scientific purists have taken offence at the expression, windows or floodgates of heaven, occurring a half a dozen times in the Old Testament books. Mr. Andrew D. White cites the phrase as one example among several of the

gross ignorance of the Hebrews respecting natural phenomena. But is it true that the Hebrews actually believed in windows or sluices in the sky which served as sources of the rainfall?

Schiaparelli, indeed, accepts the expression as literal. But even with this great master we may feel compelled at times to part company. And our other authority, Maunder, argues certainly with some show of reason that the "windows of heaven" was a purely figurative expression, since there is no sign in the sky that would have suggested even to simple minds windows or floodgates in the literal sense.

Source of the Rain. A literal interpretation of this passage supposes furthermore that the Hebrews believed in a great reservoir of water above the firmament whose streams would be let down through windows from time to time in the form of rain. But it was certainly known to many of the inspired writers that rain came from the clouds. To this effect could be quoted Ecclesiastes xi, 3, Judges v, 4, Genesis ii, 6, and perhaps the Second Book of Kings, xxii, 11.

The gifted author of the Book of Job described correctly the manner in which the clouds are formed. "He lifteth up the drops of rain and poureth out showers like floods; which flow from the clouds that cover all above." Job xxxvi, 27-28. With this knowledge that the clouds are the real sources of the rain, a belief in literal sky-windows or floodgates would seem to be inconsistent. We prefer, therefore, to hold to the milder view that explains the windows of heaven as one example among many of the bold and daring but finely poetic images used by the inspired writers.

Waters Above the Firmament. Finally, everyone will remember how in the account of the creation God is represented as having on the second day "divided the waters that were under the firmament from those that were above the firmament." Two or three times later in the Bible reference is again made to "the waters that are above the heavens." This phrase, if taken as it stands, would seem to involve a scientific misconception.

But if the firmament or heaven be understood simply of the atmosphere, then the water of the clouds may not improperly be said to be above the firmament as resting thereon, and the Scriptural phrase is acquitted of all charge of falsity. There is reason to believe that this was the sense intended. For "the Hebrews supposed three heavens," so the Century Dictionary declares, "the air, the starry firmament, and the abode of God." Is it not likely that the author of Genesis had in mind the first and lowest of these heavens, the atmosphere, whereby the waters of the clouds above are truly divided from the waters of the earth?

Science of the Bible. From the preceding summary it must appear that the sacred writings are innocent of many of the so-called scientific puerilities which it is the fashion in some quarters to impute to them. In compositions so ancient, limitations of scientific knowledge are to be expected. But in the field covered thus far, there appears in the Bible no clear indisputable case of scientific error.

On the contrary, there are in the Sacred Books the correct teachings of an earth suspended in space, of an expanse spread above the earth, and of the clouds

as true sources of the rain, lifted above the atmosphere and by it sustained. And more important still in the degree that philosophy is superior to science, there is the true philosophical teaching of a God who "upholdeth all things by the word of His power." Hebrews i, 3.

THE HEAVENLY BODIES.

Ideal of Wisdom. In the Book of Wisdom it is told of Solomon that he knew the constitution of the world, the changes of seasons, the revolutions of the year, and the dispositions of the stars. In these phrases was summed up, we may suppose, the Hebrew ideal of astronomic wisdom. How far this ideal was realized in practice, we have already partly told in our explanation of the views of this people regarding the earth and the heavens. We have now to recount some particulars of their knowledge of the celestial bodies, the objects with which the firmament is emblazoned.

General Teachings. In the first chapter of Genesis occurs a classification of the heavenly bodies, whose extreme simplicity bears witness to the antiquity of its composition. "God made two great lights, a greater to rule the day, and a lesser to rule the night, and the stars." Later the psalmist repeated the same enumeration in slightly altered form: "God made the great lights, the sun to rule the day; the moon and the stars to rule the night." And as if to declare the purpose of their being, both psalmist and prophet bade these objects give glory to the Creator. "Praise the Lord, O sun and moon;

praise him, all ye stars and light." "O ye sun and moon, bless the Lord; ye stars of heaven, bless the Lord."

In all these passages we have the same collocation of the bodies of the firmament. It is, to be sure, a grouping of the very simplest sort. But it represents a first natural and not unworthy attempt to place the lights of heaven properly in the order of that rank.

Teachings Respecting the Sun. As of the highest rank among the celestial lights, the sun is naturally the oftenest mentioned in the Scriptures. While most of the references are of too common a sort to repay recital here, a few stand out by reason of some particular significance.

Perhaps finest of all is the poetical description in the eighteenth psalm, where the orb of day is likened, now to a bridegroom emerging from the nuptial chamber, now to a hero rejoicing to run his way. Bridegroom and hero, "his going out is from the end of heaven and his circuit even to the end thereof; and there is no one that can hide himself from his heat." Besides being thus properly conceived as our chief source of light and heat, the sun was also noted in Deuteronomy, xxxiii, 14, as one among the sources of the fruits of the earth. With these attributions may be compared our own earlier description of the sun as the earth's principal source of light and heat and of the sustenance of life.

Sunrise and Sunset. To the Catholic one of the most familiar of Scriptural refrains is that which reads, "From the rising of the sun to the going down of the same." The rhythm of the phrase has commended it to Catholic and Protestant translator alike,

and there is no one that fails to appreciate its literary propriety as expressive of the fulness of the day's length.

There may be critics captious enough to take exception to the phrase on account of its technical inaccuracy. For science has now discovered that the phenomena in question are due to the earth's motion and not the sun's. And the critic may argue that in this particular the Scriptures have been guilty of an error of science. But to this criticism the answer may fairly be made that there is truth in phenomena and appearances as well as in ultimate realities. That the sun rises and sets, is not altogether false and has never been so adjudged.

Even today, when the truth is more completely known, we do not hesitate to speak and write of sunrise and sunset, even in our almanacs, prepared by scientific hands. What critic so captious as to condemn these usages because of their technical inaccuracy? And in the face of this example of present practice, what need is there of subtle argumentation to defend the Sacred Books from the charge of scientific falsehood?

There would have been guilt of error, it seems to us, only in the circumstance that the Scriptural writers, having the question distinctly before their minds, had asserted professedly that the sun revolves and not the earth. Since no such positive teaching was intended or included, the charge of error falls. The truth that resides in natural phenomena is justification by itself for the Hebraic formula, "From the rising of the sun to the going down of the same, the name of the Lord is worthy of praise."

The Moon and the Calendar. In the ordering of the national life of the Jewish people, the moon was an even more important factor than the sun. On the succession of its phases was based the month, for them a more significant division of time than the year. At the time of our Lord and probably during many centuries earlier, it was the custom for observers especially appointed for the purpose to watch for the first appearance of the young crescent moon in the west. Its appearance signalled "the new moon," a day to be observed with religious ceremonies, the sounding of trumpets and the offering of sacrifices. From the beginnings of the Mosaic ritual down to the present, "the new moons" have been kept as holydays by the Jews.

Their two chief festivals, of the Passover and of Tabernacles, were also determined from the phases of the moon. The Passover began on the fourteenth day of the first month, at the time when the first moon of the vernal season was at its highest phase. And six months later came the joyous feast of Tabernacles, beginning also like the Pasch at the full of the moon and like it prolonged for an entire week. A third great feast of only one day's duration was celebrated seven weeks after the Pasch. By bringing the Apostles to Jerusalem, this last became the occasion of our Christian festival of Pentecost. And from the Passover has been derived the date of the Christian Pasch or Easter, which is also determined by law from the full moon of the first month of the tropical year.

"God had appointed the moon for seasons," so the Psalmist announced, and the author of Ecclesiasticus added, "From the moon is the sign of the feast day."

When we remember to what extent the Israelites, living in the fields and not in towns, were dependent for many practical conveniences on the shining of the moon, we shall understand how it came to play so all-important a part in shaping their civil and religious calendar. Their month unlike ours was literal, starting at the first appearance of the crescent moon. And their most glorious festivals were made to coincide with days on which the moon was in its most resplendent phase.

The Stellar World. To the lesser lights of heaven, the stars, the Scriptures make many general references that are not uninteresting. "The orbits of the stars" is an allusion of special interest because of its occurrence in Judges, one of the earliest of their books. It was another ancient chronicler who called admiring attention to the number of the stars. "Look up to heaven and number the stars if thou canst." Genesis, xv, 5. Already they appreciated the distance of the stars as too great for measurement. "Who hath measured the height of heaven, the breadth of the earth and the depth of the abyss?" Ecclesiasticus, i, 2. From these and similar references we gather that the Sacred Writers were not inattentive to the grander phenomena of the sidereal world.

In addition, some of the more important star-groups had been singled out for special mention. Not only in Job but also in Amos, Isaias and the Fourth of Kings, we find a specification of certain definite constellations. Though translation is often difficult, it is agreed on by nearly all authorities that there is distinct and repeated reference in the Scriptures to the star-groups now called the Pleiades, Orion, and

the Great Bear. Even the amateur in astronomy needs not be informed that these three are the most conspicuous and spectacular of the constellations.

Two or three other groups were designated also, but on their correct interpretation opinion is divided, and choice must be made among the Signs of the Zodiac, the Hyades, the Lesser Bear, and some others. The problem of their identification is, according to Miss Clerke, among the most perplexing.

An Array of Texts. To the astronomer it is instructive to compile the texts that contain clear mention of individual constellations. For completeness we append them here in the translation that seems most approved by recent scholars.

Job, ix, 9: "He maketh the Great Bear, Orion, the Pleiades, and the chambers of the south."

Job, xxxviii, 31-33: "Shalt thou be able to join the shining stars the Pleiades or loose the bands of Orion? Canst thou bring forth Mazzaroth (?) in his season, or canst thou guide the Great Bear with his sons?"

Amos, v, 8: "Seek Him that maketh the Pleiades and Orion."

Fourth Kings, xxiii, 5: Some "burned incense to the sun, the moon, to Mazzaroth (?) and all the host of heaven."

Finally, there is again reference to Orion in Isaias, xiii, 10, and to "the chambers of the south," in Job, xxxvii, 9.

A Theocentric Astronomy. We have quoted these texts both for their intrinsic interest and also to justify the contention that the ancient Hebrews were in no mean degree observers of the heavens. Their knowledge, if crude, is at least worthy to be compared with

that of average men of today. Now it was on such knowledge, respectable in amount and kind, that they based their conception of the might and wisdom of Jehovah to whom their science of astronomy always reverted as its centre. "Lift up your eyes on high," cried the prophet Isaias (xl, 21), "and see who hath created these things, who bringeth out their host by numbers and calleth them all by their names. By the greatness of His might and strength and power not one of them was missing. . . The Lord is the everlasting God, Who hath created the ends of the earth."

CHAPTER XIII.

THE BIBLE AND STAR WORSHIP.

The history of nearly all the nations of the ancient world is stamped and stained with the record of their indulgence in superstitious practices. At one time their superstition took the form of idolatry, the worship of graven images, at another of nature-worship, the adoration of purely natural objects; and in nature the favorite objects of worship have been most often the sun, the moon, and the stars.

It might have been expected that the ancient Hebrews, who were lovers of nature to an extraordinary degree, would give themselves over wholesale to the same superstitious practices. Lapses of the sort did, indeed, occur, but never to meet with official sanction as in the case of the surrounding Gentile nations. On the contrary, throughout their history as the chosen people of God, their authentic and inspired books never ceased to protest against all such idolatries as abominations.

Earliest Denunciations. The first commandment of their Decalogue sounded the keynote for all their subsequent ordinances: "I am the Lord thy God; thou shalt not have strange gods before Me." By this first article of their faith the people of Israel were forbidden ever to pay homage of adoration to other than the one true God.

Later we find this general commandment particularized so as to apply expressly to the worship of the heavenly bodies. In the Book of Deuteronomy, iv, 19, we come upon a warning against all who would "lift up their eyes to heaven, and see there the sun and moon and stars, and being deceived by error would adore and serve them." That there was need of the prohibition is evident from its repetition in a later chapter, xvii, 3: "Thou shalt not transgress His covenant so as to go and serve strange gods, the sun and moon and all the host of heaven." Such was the standard set the Jewish people in the beginning by the command of God.

Lapses into Error. From this correct and exalted standard the Jewish people fell away, it is true, at many a period both early and late in their history. If these scandals are duly recorded in the Sacred Books, it is never that they may be condoned or justified. On the contrary, they were recorded only to be deprecated, and every new lapse into error was made providentially to serve as an occasion for a reiterated promulgation of the Mosaic Law. For both early and late in every period of the history, prophets and kings lifted up their voices in wrathful denunciation of these abominable practices.

Already in the time of the Judges, and hence before the days of Saul and David, the Israelites now encamped in Palestine had learned from the Canaanites the false worship of Baal and Astarte. The former divinity, the sun-god, was worshipped on the mountain-tops; while his companion, Astarte, whom Maunder believes to have been the goddess of the moon, was worshipped in groves called sacred

because dedicated to her. Everyone familiar with the sacred text will recall the frequency with which both "the high places" and "the groves" are denounced in Holy Scripture.

Phenicians and Israelites. It was chiefly from the Phenicians, a Canaanite tribe inhabiting the coast, that Israel had learned the false lesson of the worship of sun and moon. They were the nation to whom we now trace traditionally the invention of the written alphabet. And to the Phenicians of Tyre and Sidon the world owes also some of its most valuable lessons in commercial enterprise. It was adventurous merchants of this race that founded in early times the province of Carthage, which continued to exist prosperously for almost a thousand years till overwhelmed by the superior might of Rome.

But if their pioneer work in letters and trade is still remembered with honor, their religious system has long since fallen under reproach. When Israel, emerging from the wilderness into the Promised Land, had achieved its conquest of the major part of Palestine, there ensued a conflict between two religions, the idolatry of the Phenicians and the monotheism of the Jews. How steadfastly the Jewish prophets resisted the encroachments of Phenician superstition, can be read in many a chapter of the Bible. And which of the two finally conquered, is known to all the world. We owe indeed to Tyre and Sidon lessons of mental culture and commercial enterprise, but we owe to Judea, at least ultimately, our knowledge of the one true God.

THE ROYAL PERIOD.

Lapses Under the Kings. Continuing the history, we should learn how under Solomon and the later rulers of Judea and Israel, the idolatrous practices of surrounding peoples were again and again copied by the unfaithful Jews. Perhaps the most powerful and baneful of these influences came from Babylonia, where astronomy had long since degenerated into astrology and astrolatry. As Palestine fell more and more under the power of the Eastern kingdom, we can imagine how the danger grew that its monotheism would succumb to the false religion of Babylon. It is told in the Fourth Book of Kings, xvii, 16, that in the time of Osee, king of Israel, the people "adored all the host of heaven and served Baal." But Providence intervened and punished those unfaithful northern tribes by delivering them into captivity in the year 721 B. C.

The southern kingdom, with Jerusalem as its capital, was destined to survive for upwards of a century longer. And here it befell, as related in the Fourth Book of Kings, xxi, 3, that Manasses, king of Juda, set up altars to Baal and adored and served all the host of heaven, even to the extreme of bringing their worship into the very Temple at Jerusalem. But soon there came Josias, one of the wisest and holiest of Juda's kings, who cast out and burned all the equipment of the worship of Baal and the host of heaven. 4 Kings, xxiii. Continuing his work of purification, he destroyed those that had burned incense to Baal and to the sun and moon, to Mazzaroth and all the host of heaven. And he took away the

horses of the sun which unfaithful kings had placed in the temple of the Lord. Thus was restored again to its former place of honor the true service of Jehovah.

Voices of the Prophets. Would we know the true and official teaching of Israel, we must listen to the voice of her accredited prophets. At all periods these sounded the self-same note. "The prophets of Israel," writes Schiaparelli, "never wearied of threatening the most terrible punishments on star-worshippers." All who have listened to Mendelssohn's great oratorio will remember the vigor of Elijah's contest with the prophets of Baal and the issue of the conflict, and Elijah was only one of a school whose teaching never varied.

Read, for example, the books of Isaias, Jeremias and Ezechiel, the major prophets, and of the minor prophets Amos and Sophonias, for testimonies of this concurrent teaching. Listen to Isaias, of all the most eloquent, protesting against Babylonian enchantments and divinations. "Let now the astrologers save thee (if they can), they that gazed at the stars to tell thee the things that might come to thee." Isaias, viii, 19; xlii, 12-14.

Listen to Jeremias on the eve of Juda's downfall prophesying that there shall be cast out on the plain the bones of all that had loved and served the sun and moon and host of heaven, and that all these shall remain without burial. Jeremias, viii, 1-2. Read Ezechiel, the prophet of the exile, as he denounces all idolaters and especially those that stood with backs to the door of the Temple facing the east that they might adore the rising sun. Ezechiel, viii, 11; xvi, 17.

Further Testimonies. If space would allow, many other Scriptural passages could be cited to illustrate the Bible's constant condemnation of these and kindred superstitions. Some texts, as that in Sophonias, i, 4-5, would be found so plain as to need no commentary. In others the reference would be more veiled, as in the case of Amos, v, 26, where, however, it is certainly the prophet's intention to rebuke the practice of astrolatry.

Among the most interesting of these more or less veiled references are those contained in Jeremias, vii, 18, and xliv, 17 sqq. Here the prophet inveighs against those who "made cakes to the queen of heaven and offered her libations and other sacrifices." The whole point of the denunciation is missed unless it is noted that by the "queen of heaven" is meant the moon. This was the astral body which the Israelites were most tempted to adore, since it was from the moon's phases, as our last chapter related, that the Jews determined their festivals and their calendar.

Honor of the Hebraic Teaching. How remarkable and honorable it was that the Sacred Writers should thus have fought so continuously against the idolatries that beset the surrounding nations! Even astrology, a lesser sin than astrolatry, received from them no countenance. It is probable, indeed, that some Hebrews fell victims to a belief in astrological practices. But, as Schiaparelli says in a notable paragraph worthy to conclude this subject, these lapses into astrology "were aberrations of a temporary character, and it is no small honor for this nation to have seen the inanity of this and all other forms of divination. The great prophet of the exile sar-

castically reproaches the Babylonians for having faith in the 'dividers' of heaven (that is, the astrologers); while Jeremias exclaims 'Fear not the signs of heaven, at which the heathen are dismayed.' Subsequent history shows that these warnings had their effect. Of what other ancient civilized nation could as much be said?''

CHAPTER XIV.

THE MIRACLE OF JOSUE.

In the chapters just preceding we have presented examples illustrative of the relation between the Bible and astronomy. The assembling of these examples has served to make manifest that the Israelites were far from being devoid of interest in celestial phenomena. It must also have convinced the candid reader that in the cases cited there exists no serious conflict or discord between the Jewish teachings and the discoveries of modern science. There remains now for consideration one Biblical incident of peculiar astronomical interest.

Stopping of the Sun. The most remarkable narration in the Old Testament from the astronomer's point of view is that in which Josue, the successor of Moses, is said to have stayed the course of the sun. The miracle is recorded in verses 12-14 of the tenth chapter of the Book of Josue. For a proper understanding and estimation of the story of the miracle, one ought to connect it with its context by reading and weighing the earlier verses, also, of the chapter. For the moment, however, we will content ourselves with quoting only the precise passage in which the miracle is recounted.

"Then Josue said in the presence of Israel: Move not, O sun, toward Gabaon, nor thou, O moon,

toward the valley of Ajalon," or, according to another translation, "Sun, stand thou still above Gibeon and thou, moon, in the valley of Ajalon! And the sun and moon stood still till the people revenged themselves of their enemies. Is not this written in the Book of the Just? So the sun stood still in the midst of heaven, and hasted not to go down the space of one day. There was not before or after so long a day, the Lord obeying the voice of a man and fighting for Israel."

Popular Interpretation. It has been the custom in the past to interpret this passage in an absolutely literal sense. Most persons have taken the text at its face value, and have accordingly understood the inspired author to say that on the occasion of a certain battle both sun and moon were literally stopped in the heavens at the command of Josue to allow him time to bring the conflict to a successful issue. According to this literal interpretation, both of the luminaries in question paused in their diurnal journey across the sky, causing that day to be actually longer than the normal day of twenty-four hours. Indeed the popular interpretation has supposed that at the moment of the miracle the sun was about to set and the moon had just risen and that in these positions both were held for the space of an entire day.

Let it be said at once that the last element in the popular interpretation is a pure addition to the Sacred Text. Not only is it without warrant to suppose that the sun was setting, but the supposition is flatly contradicted by the geographical situation described in the narrative. For Gibeon is east of the valley of Ajalon and therefore, according to the very terms of

the narrative, the sun was at the time of the miracle towards the east, the valley of Ajalon being situate towards the west. Observe, moreover, that it is disdinctly stated that "the sun was stopped in the midst of heaven," which could not possibly apply to a position near to the horizon. In the sacred narrative, then, there is nothing to convey the impression that the sun, about to set, was detained in that position for the space of a day. There is clearly question of some other portion of the day than the evening hour.

A True Miracle. There is just as truly question, however, of a veritable miracle. The whole narrative indicates an incident not only above the ordinary, but outside the province of the forces of nature. God fought for Israel on that memorable day and lent the aid of His almighty power to the battling armies of his chosen people.

The vigorous Scriptural expression that "God obeyed the voice of a man" is of course figurative in part, since obedience to man cannot be literally predicated of the Deity. But while the form of speech is hyperbolical, the truth substantially stands that at the petition of Josue, the leader of His chosen people, God wrought a miracle to bring victory to their arms.

No one who is solicitous for the integrity and inspiration of the Scriptures can permit that the incident be interpreted otherwise than as a miraculous happening. Reverence alone would forbid us to explain the event on purely natural grounds. Here, as so often in the Bible, God is pictured as having for adequate reasons intervened to alter temporarily the ordinary course of nature. Only the infidel can deny

the possibility and even probability of such occasional interventions.

Character of the Miracle. Nevertheless, there may still remain question of the precise character of the miracle which the sacred writer meant to record. An apparent delay of the sun in its course would involve so stupendous and far-reaching an alteration of one of nature's laws, that astronomers of the utmost reverence have asked if the Sacred Text is not capable of some other well-warranted interpretation. For if the text be taken at its face value, we must suppose, not indeed that the sun and moon stood still in the sky, for their diurnal motion is only apparent, but that the earth ceased wholly or in part its movement of rotation, lost suddenly its swift speed of a thousand miles an hour, and remained at rest till the victory should have been won.

That God could have so acted with our relatively diminutive earth, no believer can deny. And if one cares still to adhere to this literal understanding of the text, one cannot be charged with want of brains, nor can absolutely convincing evidence be found in the sacred narrative to prove this interpretation false. However, it can be readily understood why astronomers, inspired with a love for both science and revelation, have sought to read more deeply into the meaning of the Sacred Text.

MODERN THEORIES.

The Passage a Quotation. It is not altogether without importance to note that the passage at issue is a quotation from an earlier narration. No mere

theory, but the dictum of the Inspired Book itself, informs us of this. For the narrative says plainly, "Is not this written in the Book of the Just?" In view of this certain fact, Schiaparelli with many others throws the responsibility for the relation back on the unknown author of the earlier volume.

This distinguished author points out, moreover, that the Book of the Just was a collection of songs concerned with the heroic deeds and great men of Israel. The poetical character of the work justifies us, he thinks, in interpreting the incident freely. And he observes rightly that "one could not conceive a more effective flight of fancy" than the representation of the stopping of the sun by Israel's great commander, "or one more fitted for the heights of an heroic and lyrical composition."

But, interesting as is this suggestion, it does not explain with complete satisfaction the fact of the incorporation of the incident in our Bible. The author of Josue, while borrowing the text, seems to have made it his own. He has given it his sanction. We might be in danger of questioning too far the truth meant to be expressed, if we resorted to the hypothesis that the narration is no more than a flight of poetical fancy. Poetical to some degree, it must contain lodged within it a kernel of truth.

A New Interpretation. A very recent interpretation by Maunder is brimful of interest as at once saving the miraculous character of the incident related and evading at the same time the astronomical difficulty. In a thorough study of the Bible story, some thirty-five pages in extent, he attempts to reconstruct the exact situation in which the Israelites were placed on

that eventful day. From an examination of the evidence he concludes that the event probably occurred in the third week of the month of July, when in that latitude the day's length from sunrise to sunset must have been of fourteen hours. The hour is noon, the sun is over Gibeon, and the moon in its third quarter is in the west resting above the valley of Ajalon.

The army of Israel has already that morning completed a twenty-mile march from Gilgal to Gibeon. It has with little difficulty raised the siege of the latter city. The besieging forces of the Canaanite kings have taken to flight towards the west and it is necessary for Josue's purposes that he should complete his task by overtaking these fleeing armies and crushing them. His own men are fatigued from their long morning march. To physical fatigue is added the trying circumstance of the burning rays of the noonday sun.

It is in this moment of crisis that Josue prays to heaven for miraculous aid. He bids the sun "be silent," for this is the literal meaning of the Hebrew word, that is, as Maunder interprets it, to cease to pour down on the earth its exhausting heat; and this part of his prayer is answered at once by the filling of the sky with clouds, from which, as the Bible relates, great hailstones descend upon the retreating Canaanites.

The Lengthening of the Day. Refreshed by the cooler atmosphere divinely provided, the hosts of Israel begin the pursuit of the enemy. On top of a morning march of twenty miles, they are able to add, through strength that only God could have provided,

an afternoon pursuit of twenty-seven miles, for such is the remarkable distance that the geography of the region proves to have been covered. God was truly fighting for Israel and in a sense had obeyed the voice of a man.

When afterwards the Israelites came to look back on that extraordinary march, they could only explain it by saying that the sun had in their favor stopped in its course. Be it remembered that they had with them no clocks or other timepieces by which to estimate the length of that momentous afternoon. They could measure it only in terms of the miles they had covered and the space traversed from noon to nightfall was equal to a full day's journey.

Truly could they affirm that "there was never before or after so long a day." How often with ourselves does one day seem subjectively longer than another! Effectively for them the sun had stopped in its course or rather retarded its speed, for the word *stopped* needs not be taken too literally. With such unwonted and unaccountable speed did they cover the ground under divine help, that the sun appeared to move more slowly than ever before.

Or better still, allowing for the poetical character of the composition, we may believe that they chose by a flight of fancy to express the effective length of that afternoon in imaginary terms of the sun's motion. When victims of ennui, do we not say, How slowly the hours creep on? and were we poets, might we not express it, The sun is moving slowly today? Similarly, the Jews kept the recollection of that prolonged interval in which they were able to accomplish so much for God. A half day had been turned by

miraculous intervention into a complete day, and it was with a certain truth that they could affirm with adoring wonder that on the occasion of their battle with the Canaanite kings the sun "hasted not to go down the space of one day."

Appreciation of Maunder's Theory. So runs the interpretation of Maunder, an authority of repute and a trustworthy guide as being both a well-informed astronomer and a devout believer. It will help us respect his opinion to know that he is by no means reluctant to concede an astronomical miracle where one is plainly affirmed. He sees, for example, in the Star of Bethlehem a purely miraculous event not to be explained by nature's laws, but due to God's providential intervention. When after minute study of the victory of Josue he concludes it to have been a miracle not of the astronomical order, but accomplished in other ways, his opinion is worth considering. It is particularly interesting as taking into account the plainly miraculous nature of the incident recorded and also allowing for the poetical character of the narrative without reducing the latter to the level of mere poesy and fiction.

Conclusion. Till the Church has supplied an authoritative interpretation of this important narrative, it would seem that we are free to choose among the various interpretations. No interpretation, however, would appear to be logical or acceptable that would rule out from this incident every element of the miraculous. For it seems to us plainly taught that on that famous "long day," God obeyed the voice of a man and fought for Israel.

CHAPTER XV.

THE FATHERS AND ASTRONOMY.

By the Fathers we understand in general the Christian writers of the first period in the Church's history. In the West the period may be held to have terminated with Isidore of Seville of the seventh century, and in the East with John of Damascus of the eighth. The important writers of this epoch number between fifty and a hundred, and their works constitute, as may be imagined, a body of literature of vast extent.

Our only present concern is to learn, if possible, what was the general attitude of this army of ecclesiastical writers towards the physical sciences, especially the science of astronomy. Explicit treatises on astronomy we shall not, indeed, expect them to supply. For their works when massed are seen to constitute a library of theology, and in such a collection we should no more look for scientific treatises than in a modern library of law. But inasmuch as the Fathers of the Church have been accused, by Andrew D. White and others, of having stayed and even thwarted the advance of science, it becomes the interest and the duty of the apologist to hunt up their scientific allusions that he may learn to what extent the charges made are true.

The Standstill of Science. It has often been alleged as derogatory to the accomplishments of the Fathers, that they contributed nothing to the progress of scientific knowledge. From our modern standpoint we may be tempted to esteem this failure of theirs a cardinal sin. But it would be wrong, in this instance as in every other, to render a verdict of guilt too hastily. We of the twentieth century are prone to forget that there are other fields of profitable intellectual exploration besides the physical, and that there may be objects of research and thought worthier of study than the material world.

The Fathers of the Church were philosophers and theologians, occupied with the problems of the world's origin and destiny, higher themes, surely, than any with which physical science is concerned. It is the fashion of the day to praise the ancient Greeks at the expense of the patristic and medieval theologians. But the distinction is to a large extent inconsistent, since both bodies of writers were at work upon the self-same themes. Philosophers like the Greeks, the Fathers were like them moralists as well, engaged in the elaboration of right rules of conduct. Finally, unlike the Greeks, the Fathers were Scriptural scholars, many of them of extensive erudition, in homily and commentary expounding with wonderful assiduity the Sacred Books in which they believed that God had given His revelation to man.

Analogous Examples. Should we be surprised, then, if men so occupied failed to add much to the world's store of scientific knowledge? Though it were admitted, as it cannot be in its entirety, that they left physical science just where they found it, could

not an explanation be discovered that would exonerate them from all blame? To justify such an apology, we do not even need to transport ourselves in spirit back to their time, a process which, however, strict fairness would demand. But in our own era we can think easily of dozens and hundreds of men of highest respectability and most beneficent accomplishment, men of books and men of affairs, jurists, statesmen, historians and others, who have themselves done little or nothing for the onward march of Science. That the careers of these men are profitless, who shall allege?

Again, the present writer has often thought of the almost parallel example of the ancient Romans. It makes their history but little less illustrious to learn that this conquering people did nothing for Science's advance. Till Pliny of the first century after Christ, what Roman was a scientist? They were a nation of soldiers, statesmen, orators and jurists, and for seven hundred years they pursued through such avenues their triumphant course. Yet what writer of today rises to charge them with a cardinal sin, because Science remained at a standstill among them for full seven centuries? With these seven centuries can we not properly compare the later seven in which the Christian Fathers were the teachers of the civilized world?

Heritage from the Greeks. Objection will be made, no doubt, that the Fathers began their career with a fairer start than the Romans, forasmuch as they were the direct heirs of the astronomy and physics of ancient Hellas. And they will be incriminated with having abused their precious heritage, by not merely

letting it lie fallow but by raising every possible obstruction to its further cultivation. Such is the tenor of Andrew D. White's accusations against them.

This well-known writer smiles at the puerilities of patristic science. He cites from among them Cosmas of Egypt as having propounded a perfectly childish theory of the structure of the earth and grafted it on the science of theology. The ready answer to this particular charge is that Cosmas' conception of the universe belonged to cosmogony and not theology, and further that it had no influence on subsequent thought. Returning to the general arraignment, White rebukes the Fathers for having clung so tenaciously to false opinions regarding the shape of the earth, the motion of the heavens, and the nature of the firmament. And, most seriously of all, he charges the Fathers with indifference and even hostility to the study of science itself.

In a few short paragraphs it is impossible to give an adequate rejoinder to these damaging complaints. But they demand some sort of reply, however inadequate it be, as emanating from an American scholar and statesman of high rank, and embodied in a work that has free and wide circulation among our college students.

DEFENCE OF THEIR DOCTRINE.

The first palliation for the reputed offence of the Fathers is that whatever false science they retail, was practically all of it derived from the very sources which it is the fashion of the day to laud in the

highest degree. As far as was consistent with their faith, the Christian Fathers were the pupils of the Greeks. It was the latter and not the patristic writers who invented the false theories of a solid firmament and a motionless earth. If Europe and Arabia down to the Renaissance believed in the Geocentric system, it was because they trusted Ptolemy the Greek, till then admittedly the greatest of astronomers. And a similar ancestry could be traced, we venture to say, for all or the major part of their scientific errors as far as these may have extended.

Restrictions Made by the Fathers. But if the Fathers were in general the heirs of the Greeks, they were not guilty of the mistake of accepting the inheritance in its entirety. To a large extent they could discern the chaff from the wheat, and were actually at pains to make the separation. It ought to be known that the scientific literature of the Grecians is teeming with the wildest and vainest of speculations regarding all matters within the scope of astronomical science. Here as elsewhere, the Greeks speculated endlessly, contradictorily, emptily, and almost aimlessly. In unfounded speculation they discoursed on all manner of astronomical subjects, the shape and size and distance of the sun, its nature and that of the moon and stars, and so on almost indefinitely, with scarcely any agreement or concomitance of opinion. There were almost as many diverse opinions as there were men.

To this motley assemblage of groundless and conflicting theories the Fathers had full access through the medium of Plutarch, the Greek compiler. Eusebius,

for example, the Father of Church History, quotes Plutarch on just these topics for over thirty pages. If Eusebius and the other Fathers grew impatient with all this ill-assorted mass of soi-disant science, shall we charge them as Dr. White does with having been false to the interest of science? Should we not rather maintain that they helped save science from its enemies?

Opposition to Science. It is only in the light of these indisputable facts that we can understand the sayings of the Fathers in which, as quoted by White, they upbraid science for its inutility. Be it noted in passing that White is wont to quote them not literally but freely, and apart from their context. Lactantius, Eusebius, Augustine, and Basil, these are the four whom he selects as representative. They are truly representative, and indeed any one of them might stand for all.

Let Eusebius be our particular choice, for he discusses astronomy more completely than the others. White alleges (Warfare, Vol. I, p. 91) that Eusebius endeavored to bring scientific studies into contempt, and quotes him as saying, "It is not through ignorance of the things admired by them (scientific investigators), but through contempt of their useless labor, that we think little of these matters, turning our souls to better things."

Who would guess from this brief epitome of Eusebius' views that the latter had devoted to the subject more than thirty pages? Who could possibly surmise that he had taken pains to write out, under the guidance of Plutarch, all the known opinions of the Greeks on some thirty-nine problems, all but two or

three of them astronomical? Let the curious read Eusebius for themselves in the fifteenth book of his Praelectio Evangelica. They will there discover, what White might well have acknowledged, that on not one of the problems are the Greek philosophers in agreement. On the nature of the sun there are nine opinions, on its size four, on its shape an equal number, on the moon's nature seven. And this discrepancy of judgment continues to the end. Moreover, a large proportion of the theories are of the most fantastic sort.

In the face of this chaotic wilderness of diverse, fluctuating and contradictory teachings, what could Eusebius do but turn away in impatience, and take up in their stead the only truth of which he felt certain, the truth of the Gospel? Such was his actual procedure. "Does it not seem to you that we have rightly and deservedly departed from the curiosity of all these men, so idle and so full of error?" He confesses frankly that he can see no fruit or utility for man in the teachings he has quoted. And he appeals for his complete justification to Socrates, the wisest of the Greeks, who in his day had adopted precisely the same stand. This and no other is the argument and spirit of Eusebius.

No Opposition to True Science. This was the temper, also, that actuated the other Fathers named, Lactantius, Basil, and Augustine. No doubt these men valued spiritual knowledge above material. But it by no means follows from this that they undervalued Science. They were scholars of extensive culture, Basil a graduate of Athens, Augustine of Carthage, and Lactantius styled because of his

proficiency the Christian Cicero. They were well acquainted with the learning of the Greeks. That they rebelled against the scientific fantasies of the latter, is not a proof that they were hostile to the advance of Science itself.

In the Imitation of Christ, Thomas à Kempis expresses a sentiment quite similar to theirs. "Surely a humble husbandman that serveth God, is better than a proud philosopher who, neglecting himself, is occupied in studying the course of the heavens." Like the Fathers, à Kempis had reason to be disgusted with the astronomy of his time, for it was beginning to be impregnated again with the virus of Astrology. By refusing to follows such pseudo-scientific teachings, both à Kempis and the Fathers did a real if seemingly negative service to the science of astronomy.

THE FATHERS AND ASTROLOGY.

"He was born under a lucky star." Language of this sort, used now only in pleasantry, recalls a form of superstition which was once accepted seriously by all men throughout the civilized world. In many a period, mankind has believed literally that the stars and planets exercised a real influence in shaping human lives. And there have been many epochs, ancient, medieval, and even modern, when astrology, the telling of fortunes by the stars, was given a rank among the learned professions.

Even now there occur occasional sporadic outbreaks of the same superstition. Along with other quacks and necromancers, astrologers are still occasionally in evidence, advertising their trade through the

columns of the press. Indeed it is affirmed by the Catholic Encyclopedia that the growth of occultistic ideas is reintroducing astrology into society.

Errors of Astrology. Whatever the popularity of this practice in the past, and whatever its prospective vogue in the near future, it is to be set down without qualification or hesitation as a delusion and a snare. To suppose that the heavenly bodies have an influence on human conduct is in its origin a pagan error, closely allied with the pagan myth that the sun, moon and stars are presided over by as many separate deities. Only thus could have originated the delusion that Jupiter and Venus would procure a blessed destiny, and Mars and Saturn a troubled one, for the children born at the time of their rising.

Nor can the cult be justified by an array of the names of those who have been its votaries. It is true that many astronomers in the past, including the great Kepler himself, have practised the astrological art, casting horoscopes for their clients. But in most cases it would be found, at least in the modern period, that these scientists merely yielded through tolerance to the weakness of their age. In true astronomy there is no place whatever for astrology.

Besides being groundless, the practice is to be condemned for its perilous moral tendencies. Distracting the soul from the worship of the spiritual God, who alone governs the universe, it substitutes for His action that of mere material objects, stars and planets, which it thus elevates to the rank of lesser gods or demons. Pretending to forecast from birth what each man's course in life shall be, it robs the will of its proper share in moulding human conduct.

The Christian Fathers. An interesting testimony to the former prevalence of this erroneous belief is found in one of Sir Walter Scott's novels, "Guy Mannering," whose whole plot turns upon the fulfilment of an astrological prediction. Reading the history at hand the novelist had learned what complete sway the cult had formerly exercised, almost down to the time of his writing. It would have interested the celebrated author to know that there was, however, one long period of history in which astrology was absolutely and effectually excluded from Christian Europe. For over a thousand years Christendom remained free from this blight, thanks to the teachings of the Fathers of the Church.

In discussing the relations of the Fathers towards the astral science, we have already shown how they purged it of some of its grossest errors. But their principal service to the science remains now to be told. For amongst all the vagaries of the science of the heavens, astrology is both in theory and in practice the most deplorable. That the Fathers placed the weight of their great authority in the scale against this superstition, is one of the most praiseworthy of their achievements.

First Efforts at Reform. At the time that the Fathers began to write, in the century just following the labors of the Apostles, astrology formed everywhere an integral part of the science of astronomy. It was taught in all the schools, Chaldean, Jewish, Grecian and Roman. Almost from the beginning the defenders of the Christian faith proceeded to attack this pernicious error, realizing how inimical it was to the spread of the truth which Christ had come to im-

part. Already in his address to the Greeks, Tatian was heard denouncing the absurdities of Grecian astronomy and astrology. This was in the middle of the second century, just at the close of what is called the Apostolic Period.

A little later, Tertullian, the famed apologist of the then flourishing African Church, placed himself on record as the uncompromising enemy of astrology. With his usual vehemence of language he declared that "of astrologers there should be no speaking even" among Christians; and went to the length of saying that "he cannot hope for heaven whose finger or wand abuses the heavens." These and many similar utterances may be found in his Treatise on Idolatry, ch. ix.

Respect for True Astronomy. With this denunciation of magic and idolatry there went hand in hand, however, a genuine respect for the proper science of the heavens. Contemporary with Tertullian, and like him one of the great Christian masters of the period, was Clement of Alexandria. To the Catholic astronomer of today it is gratifying to find this Father of the Egyptian Church giving generous testimony to the worth of astronomical science. With just discrimination he praises astronomy as "leading the soul nearer to the creative power, as helpful to navigation and husbandry, and as making the soul in the highest degree observant, capable of perceiving the true and detecting the false." Miscellanies, bk. vi. ch. ix.

Another contemporary, Hippolytus, was indeed unsparing in his denunciation of astrology. In a treatise of eleven quarto pages, contained in his "Refu-

tation of All Heresies," he riddled with merciless logic the vain pretensions of the Greek astrologers. But he showed that he had no quarrel with a well-ordered study of the heavens, by giving liberal praise to Ptolemy, the ablest of the astronomers.

A Universal Teaching. In far distant Syria, then a choice realm in the Church's patrimony, there was at the beginning of the third century another school of Christian philosophers who joined with their brethren in West and East in waging war on the same dread enemy. A Syrian work, called the Book of the Astrologers, has two quarto pages of excellent quality recounting and scoring the absurdities of current astrological practices. It is so like Hippolytus' work that one seems an echo of the other.

Perhaps the most interesting of all these concordant denunciations is that found in the "Recognitions of Clement," a patristic writing probably of the third century. Here the treatises on astrology run to full ten chapters, a sign that the author had abundant knowledge of the subject. In this work astrology is refuted particularly from the moral point of view. It is convicted of the double charge of being fatalistic in its tendency and subversive of all morality. "Men's conduct," says the author's thesis, "is due to their own free will and not to the configuration of the planets."

Golden Age of Patristic Literature. So ran on in perfect unity and harmony the steady flow of patristic teaching. It reached its climax, as we should expect to find, in the heroic writers of the fourth century, the golden era of patrology. Lactantius, the Christian Cicero, re-echoed the voices of the past in pronouncing

astrology the work of demons. And Augustine, the greatest of the Fathers, confirmed the decision of his predecessors by protesting against the amalgamation of astrology with the true science of nature.

So effectual indeed was the opposition to astrology of the earlier Christian writers, confirmed by the masters of the post-Nicene period, that the practice came to be regarded by all the faithful as a superstition and a danger, and continued to be so esteemed down to the time of the Crusades. For a full millenium, Christian Europe midst all its vicissitudes was spared the absurdities of astrological belief and practice, thanks to the patristic school of writers.

A Surprising Omission. We have thought it well to bring to light these none too well known facts regarding one important part of the astronomical teachings of the Fathers. How they could have escaped the attention of Andrew D. White, or how he could have failed to find place for them in his voluminous work, it is difficult to understand.

His book bristles with accounts of superstitions, always telling against the theologians and in favor of the scientists. But astrology is absent even from the index of his work. Had he allotted it a chapter, his numerous readers would have learned that one great school of theological writers, enduring for a thousand years, did wage war on a certain sort of science, to wit, the pseudo-science of astrology.

CHAPTER XVI.

ASTRONOMY IN THE MIDDLE AGES.

As the title indicates, this chapter is intended to relate how the science of astronomy fared in the Middle Ages, the long interval of a thousand years stretching from the fall of Rome in 476 to the fall of Constantinople in 1473. The period was for the most part, it must be confessed, rather a barren one for the science. Miss Clerke passes it by without mention in her article on Astronomy in the Catholic Encyclopedia, and Sir Robert Ball finds in this epoch no name worthy of a place in the list of the world's great astronomers. But somehow and somewhere the science was preserved; just how and where, suggests a not uninteresting chapter.

First of Two Periods. For convenience the thousand years should be divided into two great periods of about equal length. Of the earlier epoch, ending with the year 1000, it is customary to suppose that it contributed nothing to the science of astronomy. In the sense of original achievement, this may hold true. But it would be quite false if interpreted to mean that the study of astronomy was entirely neglected. Even original achievement of a certain kind was not altogether wanting.

The regulation of the calendar has always been considered one of the chief offices of astronomy.

When Dionysius Exiguus, therefore, in the sixth century instituted a new chronology in which the years were dated from the birth of Christ, and again when he determined the date of Easter from year to year by applying the so-called Metonic Cycle, he initiated changes which most certainly belong, and in no unimportant way, to the annals of astronomy.

Astronomy in the Schools. Original accomplishments apart, the amount of attention given to the science was greater than is generally supposed. The early medieval period cannot properly be called a Dark Age as far as astronomy is concerned. Even though we have not evidence that there was extensive observational study of the heavens, we have plenty of evidence that the science was cultivated with sufficient assiduity in the class-room. If we may trust the medieval programme of studies, astronomy was taught in every monastic school without exception. It was one of the branches universally prescribed. The seven "liberal arts," which every school curriculum must include, were Grammar, Rhetoric, and Logic, making up the so-called Trivium, and Arithmetic, Geometry, Music, and Astronomy, called the Quadrivium.

These studies had to be followed by all who frequented the schools, not only the boys who were preparing to be monks and who lived therefore within the cloister, but also the children who came from outside, and were intended for life in the world. These youths were put through a course of mental training which appeals even to some present-day educators as excellent in its general scheme.

What concerns us most here, is that Science had its

fixed place in the scheme, being represented by the mathematical sciences of arithmetic and geometry and the physical science of astronomy. Science of some sort, then, had its allotted place in the ordinary curriculum of the monastic schools, whose general standard, be it remembered, remained unchanged for centuries, indeed, if we mistake not, to the end of the Middle Ages.

Character of the Instruction. It may be thought that the instruction given in the science of astronomy was of the most elementary sort. It will perhaps be argued that the teaching must have been of this description since it was designed to meet the needs of mere boys and striplings. Though the rudimentary character of the instruction were to be confessed, however, this would not alter the fact, or weaken our contention based on it, that the science was taught in some fashion in all the schools and to all the pupils. Can higher or even equal claim be made for our grammar schools of today respecting the science of astronomy?

But the instruction was probably not so elementary as we have been inclined to believe. It was always the interest of the Church to encourage acquaintance with the science of astronomy, on which she depended for the determination of the dates of her movable feasts. When instructing her children in the liturgy, therefore, she would be at pains to have them understand how the days for Easter and the other festivals were computed.

Further, as we gather from the writings of many of the Fathers, astronomy was esteemed one of the noblest branches of knowledge. St. Isidore of Seville

said of it that it detaches the mind from earthly things and fixes the mind in the contemplation of what lies above. With such sentiments animating them, we may feel sure that the medieval Christian teachers could not have been content with a mere perfunctory teaching of the science.

Medieval Text Books. The mode of instruction is best surmised from the literary relics of the period, which include occasional treatises on astronomy. The latter are usually epitomes or primers, evidently designed for the use of the schools. We are told that in the monasteries no authors had higher repute as educators than Cassiodorus of the sixth century and Isidore of Seville of the seventh, both of whom composed summaries of astronomy that are still extant. The treatise of the former would cover about four pages of a modern schoolbook, that of Isidore about twenty pages. Until the eighth century, it was from these manuals or others similar to them that the teacher instructed his classes.

Short as are these chapters, they contain or suggest a fair amount of astronomical information. Based on Ptolemy, they teach of course the science of appearances. They suppose the heavens in motion and the earth at rest. Isidore makes the additional mistakes of supposing that the stars receive their light from the sun, and that comets are portents of evil.

Their Good Features. But for the most part their teachings are, if simple, yet sane and correct. They estimate the sun correctly as larger than the earth, and the latter as larger than the moon. They explain rightly the causes of eclipses both of the sun and moon. They distinguish properly between stars and planets,

Isidore supplying moreover a pretty complete enumeration of all the constellations and all the planets.

The general utility of the study is particularly well expressed by Cassiodorus, who reckons among its uses the forecasting of the weather, the keeping of time, the determination of the paschal feast, and finally the proper understanding of solar eclipses that simple people may not be disturbed or frightened when these occur. Elementary, then, as are these expositions and even unoriginal, they are, it appears to us, wise in their selection of materials and well-suited to the purpose for which they were created.

One excellence in these little manuals that ought not to be overlooked is their protest against the abuses of astrology. Distinguishing correctly between "natural" astrology, the forecasting of the weather, and "judicial" astrology, the forecasting of men's lives, both of them reject and condemn the latter as false and even contrary to the faith. And this remained the attitude of the Church, we have reason to believe, throughout the earlier medieval period.

St. Bede and His Followers. Far more elaborate treatises on astronomy appeared in the eighth century from the pen of St. Bede, the pride of the English Church and the most scholarly man of his time. These compositions, intended some for professors and others for pupils, would constitute in modern print an octavo volume of fully five hundred pages. Of the same doctrinal tendency as the earlier treatises mentioned, they are far more learned, abounding in textual details and in apposite diagrams and illustrations. A recent article in the Catholic University Bulletin informs us that St. Bede's manual became the most popular one in the classes of astronomy.

The valuable educational work of St. Bede was supplemented by that of Alcuin of England and Rabanus Maurus of Germany, who flourished respectively in the latter half of the eighth century and the first half of of the ninth. Both of these monks were teachers of renown, and composed manuals on the seven liberal arts, including astronomy, suited to the particular needs of their pupils.

The Monastic Ideal. From all that has been related above it would appear that in Christian Europe during the early Middle Ages fair attention was given to the science of astronomy. In the collapse of the other physical sciences as far as this may have occurred, astronomy did not share. No doubt the work of the schools, as every other peaceful enterprise, was destined to suffer much during the ninth and tenth centuries from the devastating invasions of the Danes and Normans.

But the monastic ideal was never entirely submerged, and this ideal, with its threefold exhortation to prayer, manual labor and study, remained the saving influence of the Middle Ages, even in its darkest days, and ultimately effected the civilization and Christianization of the barbarian tribes of the north and of all Western Europe.

LATER MIDDLE AGES.

That there was some cultivation of astronomy on the part of Christians in the early Middle Ages, our previous section has, we think, sufficiently demonstrated. This section insisted on the fact that in the monastic schools then dominant, astronomy was one

of the studies universally prescribed. For aid in the study, it was further urged, handbooks and treatises were provided by some of the best of the medieval educators.

Limitations and Their Reason. If the instruction lacked the fullness that other times and places have exhibited, the explanation is not that the Church or the medieval Christians were averse to learning, but that Christians of the Latin rite had gradually lost acquaintance with Greek, the language of practically all the early masterpieces in astronomical science. Latin, the language of the ancient Romans, had come to be the current means of communication in all the lands of Western Europe, particularly in the schools. Now the ancient Romans, as we have already had occasion to remark, were but little if at all devoted to the physical sciences and left no scientific monuments of worthy character.

If, again, learning suffered a decline in the ninth and tenth centuries, the reasons were political rather than theological. The terrible descent of pagan and barbarian Danes and Normans on the coasts of France and the British Isles, undid for the nonce the salutary accomplishments for education of the preceding centuries. What Christian missionaries and teachers had done for the first hordes of barbarian invaders, in civilizing the Goths of the continent, the Vandals of Africa and the Saxons of England, this beneficent work the Church must begin again in favor of the Huns of the East and the Danes and Norsemen of the North. It was inevitable that, while the task of their amalgamation and Christianization was in progress, learning and scholarship should suffer.

Career of the Arabians. Meantime in another part of the world, dominated by an alien and inferior religion, science found a temporary refuge. We do not need to sympathize with the religion of the Arabians, that of the prophet Mohammed, to admire the services they rendered to physical science in the medieval period. It would be going against the facts of history not to acknowledge that physical science owed its preservation during the Middle Ages chiefly to the schools and scholars of the Arabian or Mohammedan Empire.

What a wonderful and indeed romantic history was that of the Arabians during this era. In military annals the seventh century and the first two decades of the eighth were the period of Arabian glory. In the hundred years from the Flight of Mohammed in 622, they effected the conquest of southeastern Asia, all northern Africa, and Spain, all told of half the civilized world. Their empire established, they had then settled down in a measure to the more peaceful pursuits of commerce and learning.

Transferring now their caliphate or seat of government from Damascus in Syria to Bagdad in Mesopotamia, they soon made of the latter the grandest city in the world, a metropolis of well-nigh two million inhabitants, the world's chief centre of government, commerce and scholarship. A century or more later, there was established an independent caliphate at Cordova in Spain, which was destined to rival the eastern metropolis in its devotion to learning, and which became one of the channels through which scientific knowledge streamed back into Christian Europe.

Their Service to Astronomy. We write "streamed back" advisedly, for it is not to be forgotten that it was from Christian hands that the Arabians received in the first instance the treasures of Hellenic science. The Arabians came late into the field, and owed to the Christians of Damascus in Syria and of Alexandria in Egypt their first acquaintance with the Grecian masters. If Eudoxus and Hipparchus and Ptolemy were now put into their hands, it was because the productions of these geniuses as well as all the other masterpieces of Greek literature had been carefully guarded for many centuries by the Christians of the East. But the credit belongs to the Arabians that they proved not unworthy custodians of this priceless heritage. Some of their particular achievements in astronomy must find a place in our narrative.

To this interesting people we owe the Arabic numerals, so much more convenient than the Roman. We owe them some of the commonest words in astronomical terminology, such as almanac, azimuth, zenith and nadir, as well as the actual names of many separate stars, as Algol, Aldebaran, Vega and Deneb. Their name is written large in the vocabulary of the science. Moreover they constructed calendars and predicted eclipses, using for the latter purpose the Saros cycle discovered by the Babylonians perhaps two thousand years earlier. Finally they pursued the detailed study of the constellations with the assiduity for which the Orientals have been famed in many a period of history.

It may not be claimed, however, that they contributed notably to the progress of the science. They lacked the qualities of originality and inventiveness.

Not only was Ptolemy their acknowledged master, but his works were esteemed too sacred to allow any alteration at their hands. A further defect in all their astronomical work was its complete subordination to the superstition of astrology. Devotion to the latter delusion seems to have been in keeping with all the traditions of their race.

Arabic Influence in Europe. There can be no doubt that it was from the Arabians that Christian Europe came later to learn again the science of astronomy, when the terrors of barbarian invasion had passed away. The most scholarly man in Christendom at the end of the tenth century was Gerbert, who had received his schooling in the Arabian colleges of Spain, then in the zenith of their glory. A happy event is it in Church history that in the pivotal year 1000 Gerbert, the scholar, under the name of Sylvester II, was reigning as Pontiff over all Catholic Christendom.

The example of Gerbert is but one indication of many that Spain was the avenue through which the riches of astronomical lore found their way back to Christian Europe. The first observatory in Europe, a structure of palatial grandeur if the engravings are to be trusted, was erected at Seville in 1196. A hundred years after, King Alfonso X of Castile drew up, with the help of Arabian and Jewish scholars, the so-called Alphonsine Tables, and won for himself an honored place in the history of the science.

It is not, however, in the medieval period, even in its later centuries, that Europeans shall give evidence of astronomical achievement of original and progressive character. Their instruments for observation were still of the crudest sort. The optical lenses

invented by Roger Bacon in the thirteenth century, must wait for over three hundred years before being put to use by Galileo in an astronomical telescope. Albertus Magnus, also of the thirteenth century, a student of nature through books, was hampered in his study of astronomy by being obliged to forage through poor, blundering, and second or third-hand translations from the Arabic of Ptolemy's Almagest. Worthy scientists as were both Bacon and Albertus, they were denied the means for advancing astronomy along proper lines.

An Era of Astrology. Unhappily also, and this is from the Catholic viewpoint the saddest chapter in the entire history of astronomy, unhappily Europe had inherited from the Arabians the superstitions of the ancient astronomy as well as its excellences. Consequent on Arabia's bequest to Europe, there began in Christendom an era of astrology. From the twelfth to the fifteenth century the influence of astrology grew in force till it infected almost all classes of society. Astrology was the order of the day, as is frankly avowed and detailed by Pastor in his History of the Popes, and by Jacobi in the Catholic Encyclopedia.

It mattered not that theologians of the stamp of Aquinas protested against it, reckoning it with other superstitions. Nor was the opposition of Petrarch sufficient to save Europe from its onset. St. Bernardine and other missionary preachers tried to stem the tide, but for the moment without avail. It was destined to run its course. In the troubled days of the fourteenth and fifteenth centuries astrology found too many willing adherents and for a time threatened even to become a substitute for the true religion.

Overthrow of Arabic Influence. Astrology, however, could not triumph ultimately. Its essential falsehood, unperceived by Arabians, forced itself on Christian minds when Arabic influence began to wane. Its essential heathenism could not survive the partial resuscitation of paganism that was one feature of the Renaissance. There came the dawn of a better day when worthy astronomers, like Regiomontanus in Germany, and Cardinal Nicholas de Cusa in Italy, entered the field and paved the way for the radical reform which another Catholic ecclesiastic, Copernicus, was soon to initiate. The final issue would be a last sign proving the essential superiority of the Christian over the Mohammedan religion. For Christianity makes for progress, Mohammedanism for stagnation. Christianity abhors superstition, Mohammedanism welcomes it.

CHAPTER XVII.

REFORM OF THE CALENDAR.

As we emerge from the medieval into the modern period, we come upon two events in astronomical history worthy of being penciled in high relief. The first, belonging to the theory of the science, was the the substitution of the Copernican for the Ptolemaic system. Of the vast significance of this departure, we have already spoken at length.

The other, belonging to astronomical practice, was the reform of the calendar, consummated by Pope Gregory XIII. This pontifical act may well be emphasized by Catholics not only because of its great scientific and practical importance, but still more because of its clear revelation of the attitude of the Church toward astronomy in the period just preceding the celebrated trial of Galileo.

Pontifical Acts. Twice in history has the calendar been revised on truly scientific principles, first by Julius Caesar in 46 B. C., and again by Gregory XIII in 1582 A. D. In both instances, as Dr. William Barry happily observes, the reformer acted in his capacity of Pontifex Maximus or Supreme Pontiff of the received religion. In both instances the prime motive for the reform was the regulation of religious festivals. In each case it was the ecclesiastical calendar that was paramount in the Pontiff's mind.

Of necessity, however, the civil calendar was altered and regulated at the self-same movement, a consequence which widens very much the interest of the event. And further, aside from motive or consequence, the reconstruction was in each case based on astronomical data, a procedure which entitles the achievement to a place of standing in the history of the sciences.

Nature of the Calendar. The calendar is known to most persons as a printed set of tables, revealing at a glance the length of the year and of the months, and particularly the agreement of week-days with dates throughout the year. The current calendar, for example, tells us that this year (1909) shall consist of 365 days, that February shall be of ordinary length and not increased, as in leap year, by one day, and that the first of January shall fall on Friday, a like fixation being indicated for every other date.

Not everyone stops to think that underlying the calendar is a certain definite system of reckoning time and distributing it into its proper divisions. To be of permanent value the system used must be most carefully framed. An arbitrary or merely conventional system would not answer. In the last analysis the method must rest on the divisions of time that nature itself supplies. When, however, as often happens, the natural divisions are unequal or fractional, it is permitted to use an average result.

Of our four larger divisions of time one, the week, is indeed purely conventional, bearing no relation whatever to any fact in nature. But the remainng three are founded on astronomical facts, the year being based on the sun's apparent circuit among the

stars, the month on the moon's similar but swifter journey, and the day on the sun's diurnal revolution. Of these the day and the year are clearly the two of greatest practical importance. The day determines the normal hours for labor and rest, while the year determines the seasons and consequently the times when the earth shall bring forth its fruits and in turn rest from labor. Both these determinations, be it noted, are absolutely independent of man's control. The calendar that neglects them or assumes independence of them must inevitably perish.

The Julian Calendar. Anciently all calendars were exceedingly imperfect. Judea, Egypt, Greece and Rome had each its own method of apportioning time, but the results were never better than approximate. One source of complexity and error was insistence on the month rather than the year as the unit of time measurement. The lunar month with its quota of 29½ days, could only by the most indirect methods be made to synchronize with a year of 365 days. So long as the month was emphasized and the year subordinated, a satisfactory calendar was impossible.

The first step in Caesar's reform was to give the year the place of preference in the calendar and to divide it arbitrarily into twelve calendar months of almost equal length. The course of the months no longer agreed with the course of the moon but was made to suit the year. The length of the months was no longer the 29½ days of interval from one new moon to the next, but became 31, 30 or 29 days, according to the month, in such manner, however, that the sum of the twelve totaled 365 days. The wisdom of this

substitution of an artificial for the natural month has commended it to all subsequent ages.

A still more radical change had now to be made. Into such confusion had the calendar fallen that in Caesar's time there was a difference of some eighty days between the calendar's reading and the sun's position in the heavens. To rectify this huge error, the emperor decreed that eighty additional days should be inserted in a certain determined year, that thus the calendar might be brought into alignment with the celestial events it was intended to represent. This abnormal year lasting 445 days has since been known in history as "the year of confusion." By its means, however, the equinoxes of the calendar and of the heavens were brought into harmony, and a fresh and proper start was effected.

Exact Length of the Year. The most delicate part of the problem remained still to be solved. For the astronomical or true year, that is the time from equinox to equinox, measures not an even number of days, 365 or 366, but a fractional number between the two. It was imperative that the length of the year should be determined with utmost accuracy before the new calendar rules were proclaimed.

As in his earlier corrections, so in this determination, Caesar took counsel of the Greek astronomers of Alexandria. On their computation that the solar year measures 365¼ days, he based his final ruling to the effect that, while the normal year should be composed of 365 days, every fourth year should have added to it an extra day, placed in February which was then the twelfth month, the result being what we now call a leap year. Thus was completed the scheme of the

Julian calendar, which remained the norm for all civilized nations down to the reign of Pope Gregory XIII.

There would have been no need of a later reconstruction of the calendar had the Alexandrian computation been completely accurate. But it was in error, by a small amount, to be sure, only the 1-128 part of a day, but enough to cause a variation from the truth of one day in 128 years. The discrepancy was sufferable for a time, but it necessarily continued to increase so that in the sixteenth century the error amounted to fourteen days. Reckoned from the Council of Nicaea of the year 325, which had fixed the rule for Easter, the variation was somewhat less, ten days instead of fourteen. The actual net consequence in Gregory's time was that whereas the vernal equinox was celebrated in the calendar on March 21, in the heavens it occurred ten days earlier, on March 11.

The Gregorian Calendar. As Easter day was determined by Church law from the vernal equinox, this increasing error became a matter of solicitude to the Roman Pontiffs. A century before Gregory, they had begun to institute means for making the proper corrections. They engaged the services of the ablest astronomers of the time, as Regiomontanus in the fifteenth century and Copernicus in the sixteenth. With wise caution they delayed decision till all the required data had been accurately ascertained. Finally in the year 1582, Pope Gregory XIII, applying the finished results of the Jesuit astronomer, Fr. Clavius, proclaimed the calendar that bears his name.

His alterations did not need to be so radical as those of Caesar, but in two respects they were the

same in kind. The immediate error he corrected by dropping outright ten days from the year 1582, skipping at once from October 4 to October 15. The intervening dates will be found nowhere in Catholic history, owing to the summary but wise excision made by the Holy Father.

To prevent recurrence of error, he further decreed that thereafter the centesimal years, as 1700, 1800 and 1900 should not be leap years, unless they were evenly divisible by 400, as is the case with 1600, 2000 and 2400. We owe it to Gregory, therefore, that 1900 was not a leap year and that 2000 will be one. In general we owe him an adjustment of the calendar as nearly accurate as possible. If the slight error of one day in 3,325 years was permitted to remain, it was that the rule determining leap years might be a convenient one and easily applied, and because it was felt that the error that will have arisen after 3,000 years have passed can easily be corrected.

Church's Attitude Towards Science. Gregory XIII has no calendar month named after him as has Julius Caesar, but his name is immortalized in the proper title of the calendar under which we now live. It is pleasant to note that the honor of reforming the calendar in modern times fell to one who was at once a benign ruler and a warm patron of learning. It does not detract from his honor to say, however, that his accomplishment was but the final step in a papal enterprise that had been maturing for a hundred years.

This enterprise is, it seems to us, the best possible witness of the Church's general attitude toward astronomy in the sixteenth century. If fifty years after Gregory's reform the Church saw fit to condemn the

great Galileo, it must have been for some other reason than aversion to astronomy and hostility to the advance of science.

Galileo was already alive, be it known, and had even reached his eighteenth year, at the time that the Roman Pontiff proclaimed the reconstruction of the calendar. Whether in Galileo's maturer years the Church's mind respecting science had become materially altered, is a question that awaits discussion at our hands in a later chapter.

RECEPTION OF THE NEW CALENDAR.

Meantime, as an additional preface and help to a proper understanding of the Galileo case, we may well carry a little farther the history of the calendar. The story of the Pope's reform of the calendar is not complete till there is added an account of the manner in which it was received by the different countries of Europe. Knowing as we do now that the reform was a distinct advance in astronomical practice, we are curious to learn if it was immediately recognized as such and universally adopted. All astronomers of today agree in commending the action of the Holy Father as agreeable to the demands of scientific truth. But it would be a hasty inference to conclude that such commendation was universally bestowed on the Holy Father's act from the beginning.

The truth of the matter is that the Protestant States were very reluctant to accept the proposed reform. Germany in its non-Catholic sections held out against the reconstructed calendar for over a hundred years, England for almost two hundred,

while in Russia the opposition has lasted down to the present day. A somewhat detailed consideration of these facts may prove instructive.

Attitude of Various Governments. Of Catholic countries it is almost superfluous to speak in this connection. It goes without saying that they adopted the revised calendar at once, for their spirit was one of perfect submission to the decrees of Rome. In Germany and Denmark, on the contrary, the new calendar had to fight its way into favor against determined opposition, and was not finally adopted till the year 1700.

Long before this date its case had been fully and fairly presented before the legislative assemblies of these two Protestant countries. We read, for example, that Kepler, the eminent astronomer, himself a Protestant, appeared before the German Diet in 1613, pleading the cause of the Gregorian reform. He was fully persuaded of its wisdom and its truth. He believed in it as firmly as in the Copernican system of the heavens. But though he advocated it with all the authority of his office as Astronomer Royal of the Austrian Empire and with the wealth of argument that only a Kepler could muster, his plea was rejected and the Gregorian calendar remained excluded from this Protestant realm till the close of the century.

England's Delay. A similar fate awaited the new calendar in England. Owing to anti-papal prejudices, coupled perhaps with alleged arguments of inconvenience, the English Parliament midst its many vicissitudes refused to ratify the suggested change of dates and system until the year 1752. In the meantime there had occurred the scholarly ages of Elizabeth

and Anne, with the troubled period of Cromwell and the Charleses intervening. The country had admitted many changes of political system and dynasty, but had remained obdurate in its opposition to the Gregorian code.

Moreover, before the final acceptance, England had seen arise within its borders a brilliant group of world-famed astronomers, a Newton, a Flamsteed, and a Halley. It is fair to suppose that these scientists appreciated the worth of the papal reform and lifted up their voices in its behalf, but popular prejudice, as the history manifestly records, retarded till after their deaths the much-desired ratification.

Finally it would surprise us, were we not already acquainted with the fact, to learn that in Russia and the so-called Greek Churches of the East, the Julian calendar is followed to this day, with the result that their year now lags twelve days behind that of Western Europe.*

Significance of the History. We should be loath to emphasize these admitted facts of history, had not so much been made of the Church's conduct towards Galileo by an army of anti-Catholic historians. Both sets of facts ought best perhaps to be allowed to rest in peace, as unfortunate exemplifications of human infirmity. But since the Galileo case has been exploited far and wide, and will doubtless continue an object of discussion indefinitely into the future, we feel constrained to lay stress on what appears to us a quite parallel case, in which governments other than the papal were the offenders.

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* Recent advices tell us that Russia has decided to adopt the Gregorian Calendar in 1912.

In the matter of the Gregorian calendar there is question, not of an astronomical speculation or theory, but of an established scientific truth. A first refusal to embrace it might fairly be attributed to caution. For conservatism will always halt before radical and revolutionary changes. But in the case at issue the refusal persists, lasting for one, two, or three centuries, in one or another country. They that persevere in their opposition are responsible governments, as authoritative with their subjects as the Roman Curia is authoritative over all Catholics.

The point of permanence is made to forestall the charge that will surely be registered against Rome that the Catholic Church persisted in her opposition to Galileo's doctrine, allowing the condemnation of Copernicanism to remain technically on her books for almost two hundred years. The English Government's condemnation of Gregorianism, for such it may truthfully be styled, lasted well-nigh as long, from 1582 till 1752.

Finally, the motive underlying the rejection of Gregorianism by the Protestant States was chiefly sectarian prejudice and intolerance. We dislike to use terms that connote one of the most unpleasant phases of human temper and action. But softer words would hardly express the reality. Rome's motive, on the other hand, in instituting proceedings against Galileo, was the defence of the Holy Scriptures whose authority she thought, perhaps mistakenly, to have been impugned.

Parallels in History. A fuller understanding of this parallel will appear when the Galileo incident shall have been reviewed. But on the basis of what has

been cited above, we submit that there is a parallel, which ought not to be disregarded. As far as our knowledge reaches, it is a parallel that has never been properly accentuated in any one of the numerous discussions of the famous trial and condemnation of Galileo.

As a mere statement of fact, we plead that as serious charges of opposition to the advance of science might be made against the non-Catholic courts of Europe as have so repeatedly been preferred against the Roman Curia touching the case of Galileo. We submit this, however, without sympathetic endorsement of the charges on either side. We offer it merely as a fair rejoinder.

CHAPTER XVIII.

GALILEO AS A PHYSICIST.

The name of Galileo has become familiar to all students of history because of his condemnation by the authorities of the church. Putting aside for the moment all consideration of Galileo's conflict with the church authorities, a study of Galileo as a physicist and of the part he played in the development of man's knowledge of the physical world becomes a matter of interest.

To appreciate the importance of his achievements, something of the earlier history of physical science should be known, and in particular how the world had for almost two thousand years been committed to the physical system of Aristotle, the ancient Greek philosopher. All through the Middle Ages, scholars, both Christian and Arabian, looked upon Aristotle as an unquestionable authority, hailed him as their master, and drew from his works their entire system of physical science.

This was not unnatural in view of the fact that Aristotle was the greatest genius of antiquity. He is still acknowledged as the first great naturalist in the order of time, and is regarded as one of the greatest philosophers of all times. It is no disparagement to his general talent to say that his physics, both of the heavens and the earth, was faulty and incomplete.

That he was interested in physics, his many works on that subject are evident proof, but his assertion of facts seems often to have been incorrect and his solution of physical problems is today unsatisfying. He insisted too much on the method of deduction, employing too little the method of induction and experience.

The Middle Ages Followed Aristotle. The Middle Ages, engrossed in other and, it may be claimed, better and more important things, did not take time to correct the errors and revise the methods of Aristotle. And so through natural causes, there came down to the sixteenth century a heritage of physical science that must be described as meagre and inexact. To correct the errors and revise the methods of Aristotle there was need of a genius who should make a new study of nature's laws.

It was the achievement of Galileo to bring about the renaissance of physical science and lay the foundation for the wonderful advances in physical knowledge that have signalized the last three hundred years. At Pisa, Italy, in February, 1564, was born Galileo Galilei, the father and founder of modern physics. His father was not wealthy, and, burdened with a large family, was unable to provide expensive instructors for his children, yet, becoming every day more sensible of his eldest son's talent, he decided, at whatever cost, to give him the advantage of a university education. Accordingly young Galileo, in his eighteenth year, was entered at the University of Pisa, to prepare for the medical profession.

First Signs of Future Greatness. It was at this time that he made the first and not the least inter-

esting of his discoveries. While praying one day in the Baptistery of Pisa, his attention was drawn to the great sanctuary lamp, which, after being lighted, had been left swinging. It struck him as a significant fact that whether the arc through which the lamp oscillated was great or small, the time occupied in each swing was apparently the same. He proceeded to compare its oscillations with his pulse beats and he found that the time of each vibration remained the same, even after the motion had greatly diminished. Thus was discovered the first law of the pendulum.

He first applied this law to the construction of a pulse gauge which aided physicians in counting the pulse beats of their patients. In later years Galileo improved this invention and prepared the way for the modern pendulum clock which was invented by Christian Huyghens in 1668, just sixteen years after Galileo's death. The pendulum has since been put to other uses besides that familiar one in the pendulum clock, and today its study occupies a fairly large chapter in manuals of physics. It is not to be forgotten that Galileo was the first to direct the world's attention to it, the first to announce its laws and suggest its use.

Aptitude for Mathematics. It was during his academic career that his talent for mathematics first became manifest and induced him to abandon his medical books for the more congenial problems of Euclid and the fascinating treatises of Archimedes and other ancient geometers. He even improved upon the methods of Archimedes, the greatest of the Greek physicists, and invented an instrument which

in its uses was very similar to our present hydrostatic balance. This invention, joined to his previous discovery of the laws of the pendulum, secured for him a widespread reputation and the intimate friendship of many of the distinguished personages of Italy. It is not surprising, therefore, to see the chair of mathematics at the University of Pisa conferred on him, though he had scarcely attained his twenty-fifth year.

Flattered by this distinction, the young professor left nothing undone that was calculated to justify the preference that had been shown him. Conceiving that the basis of all physical study rested on the laws of motion, he endeavored to establish these more firmly, not by hypothetical reasoning, as was the custom of the time, but by real experiments. In this he incurred the enmity of his fellow philosophers and scientists, who were loath to depart from the ancient and time-honored methods of Aristotle.

In his attempts to formulate the laws of motion he refused to accept Aristotle's theory of falling bodies, which claimed that the velocity of a falling body depends on its weight, or, in other words, the heavier a body is, the less time will it require to fall from a certain height to the earth.

The Experiment at Tower of Pisa. Having satisfied himself of the falsity of this belief, which had received the sanction of the learned for nearly two thousand years, he resolved to vindicate his position in a public demonstration. Yonder leaning tower of Pisa, which seemed to have bent over purposely to facilitate the experiment, offered an ideal spot for the demonstration. One morning, before an immense concourse of people,

including the assembled university, Galileo ascended the tower and let drop from its top simultaneously two shots weighing one and one hundred pounds respectively. According to the current belief the heavier shot should reach the ground first, but such was found not to be the case. The multitude of spectators, to their great amazement, saw the two balls start together, fall side by side, and reach the ground at the same moment.

Thus the first great step was taken in the overthrow of that imperfect system which had impeded the development of physics and other natural sciences for over nineteen centuries. On the basis of these and similar experiments, Galileo was enabled to announce the laws of falling bodies—a subject which now forms one of the basic chapters in the science of mechanics.

Becomes Professor in Padua. But Galileo was in advance of his time, at least at the University of Pisa, and in 1592, because of the novel and unwelcome character of his teachings, he was obliged to resign his chair after only three years of tenure. Undaunted by this reverse of fortune, he went to Florence, where he met some friends who were influential enough to secure his appointment to the chair of mathematics at the University of Padua. Not all the universities were hostile to the new teaching, for at Padua he enjoyed perfect freedom. All the time he could spare from his professional duties he employed in private study and in making incessant experiments. Chief among his inventions at this time was his air thermometer. The original idea of this instrument belongs to Hero, the Greek mathema-

tician, but Galileo was the first to construct it in practical form.

Galileo's genius, now ripening into maturity, began to startle the world with its revelations in physical science. He was the first to show that the path of a projectile is a parabola. Previously it had been believed that a cannon ball or missile moves forward first in a straight line and then drops vertically to the ground. The phenomenon he explained by stating that any body projected into space is constantly being acted upon by gravity and thereby gradually attracted to the earth.

Discovers New Principles. His famous principle of the parallelogram of forces, which practically started anew the study of dynamics, was discovered at this time, but its importance and significance were almost forgotten in the excitement and enthusiasm aroused by the greater discoveries soon after to follow. Early in the year 1609 a report was circulated that a spectacle-maker of Middleburg in Holland had constructed an instrument by which distant objects were made to seem nearer. Galileo on hearing this puzzled his brain as to the possibility of constructing such an instrument.

Concluding that this phenomenon had its basis in the theory of perspective, he began to experiment with spherical glasses, and his first telescope consisted merely of a leaden tube with two lenses, one plano-concave and the other plano-convex. It made objects appear three times nearer. Enthused by this success, he spared neither time nor labor in his efforts to improve his invention, and he finally secured a telescope that would make objects appear thirty times nearer.

If the invention of the telescope does not strictly belong to Galileo in the order of time, since, as we have seen, a Dutch spectacle-maker accidentally discovered the principle while working with lenses, it remained for the Italian genius to perfect it and to divine its real value.

First to Use Telescope on Heavens. Galileo was the first to turn the telescope upon the heavens, and he observed there what no mortal eye had seen before: the craters and deep valleys of the moon, the various phases of Venus, the four satellites of Jupiter, the separate stars of the milky way, the nebulae, and the whole heavens dotted with myriads of stars of which man had never dreamed. So widespread was the fame of Galileo after this discovery that he was beseiged with orders for telescopes from all parts of Europe. As a recompense for his ingenuity, his commission as professor was prolonged for life with a salary triple that which he had previously received.

The remaining years till his death in 1642 are less pleasing to contemplate, for it was then that he became embroiled in controversies with other scientists and with the church authorities. Moreover, little in the way of new invention occurred to make this period memorable. That he was not entirely idle, however, is proved by the fact that in 1637, only six years before his death, his telescope revealed to him one other astronomical fact of no little importance, the moon's libration, as it is technically called.

Summary of Galileo's Achievements. Summing up Galileo's achievements, we may say that he did much for physics both theoretical and applied. By his discovery of the laws of falling bodies and of the prin-

ciple of the parallelogram of forces, and by his discussion of centrifugal force, he laid the foundation of modern dynamics. To the practical side of his science he also contributed by his invention of time-keeping devices and the construction of thermometers, and by his reconstruction of the telescope. Moreover, he so stimulated research and scholarship that there followed in his wake a long line of great physicists, culminating in Sir Isaac Newton, and within less than a century from his death mechanics was practically a completed science.

We ought not to obscure the fact that Galileo had his limitations. His inventions were crude and had to be perfected later. What he started, others completed. Again, his reasoning in favor of the Copernican system was not always satisfactory. But these limitations were natural, for Galileo was in reality a pioneer, and as such deserves the highest admiration, and will ever be regarded as the founder of experimental science and one of the world's greatest physicists.

CHAPTER XIX.

THE CONDEMNATION OF GALILEO.

The case of Galileo has been used now for two centuries as a stock argument against the teaching authority of the Catholic Church. It has been alleged not merely that the Roman congregation was guilty of a misjudgment in condemning Galileo, to which Catholic writers have long since agreed, but that she thereby proved herself adverse to the progress of science and forfeited her claim to doctrinal infallibility. Galileo himself has been pictured as the victim of injustice, a martyr for science, tortured, imprisoned, and otherwise made to suffer for his opinions.

We shall not attempt to exonerate completely the tribunals that were involved. But we hold it right to demand of all interested that they examine the facts fairly and exercise that justice of judgment which, it is complained, Galileo did not receive. Otherwise their judgment is as reprehensible as that of the Roman tribunals taken at its worst. To be false to historical truth is as blameworthy as to be hostile to science.

An Estimate of Tribunals. Galileo was an illustrious scientist, the founder of modern physics and of descriptive astronomy. The fame of his genius has given to his trial an importance it would not otherwise have

had, and has compelled the sympathy of subsequent generations. Had he been less famous a scientist, the incident of his condemnation might almost have fallen into oblivion.

Not one in a thousand of those who sympathize with Galileo is aware that in precisely the same epoch, in the year 1624, three scientists or philosophers were condemned by the Sorbonne of Paris for anti-Aristotelian views in almost the same terms as Galileo, were banished by the French Parliament, and they and all others forbidden to hold or teach such opinions under penalty of death.

This incident is lost to view in the greater glow of the celebrated trial at Rome. It may be usefully recalled as illustrative of the spirit and temper of the times. Faulty as was the action of the French University and Parliament, the question may well be asked if they thereby proved themselves deliberately hostile to the advance of science. Would it not be truer to say that, though mistaken, they had followed their best lights? Who, moreover, insults the memory of the Sorbonne and Parliament by perpetuating the memory of these facts to their discredit? Or who refuses them respect because of their mistaken judgment and unjust sentence?

Though Galileo was a greater scientist than the three condemned in France, and though the Church is greater than the Sorbonne or the French Parliament, the principles for judging the two cases remain essentially the same. Great as was Galileo, the tribunals of the Church felt in the final issue that they could be no respecters of persons. Reluctantly but conscientiously, they felt called upon to censure a man

even of his fame. The greatness of the accused undoubtedly operated in his favor, as the entire history proves, but could not finally save him. His very eminence precludes the probability that the tribunals acted from base or unworthy motives. To attribute such to Gallieo's judges is as unwarranted as to impute base designs to a civil court from whose unjust action an innocent man is unfortunately made to suffer.

We insist upon these considerations that proper allowance be made for the action of what was after all a human tribunal. Entitled to the highest respect, the Congregations of the Inquisition and Index are not, however, the infallible teaching Church. Infallibility is a unique prerogative granted only to the Pope as sovereign teacher in matters of faith and morals. The Congregations are commissions or tribunals, discharging most important functions for the security of faith and morals, but not altogether free from the possibility of issuing some decisions that shall afterwards be reversed. To their acts, human rather than divine standards should be applied.

The Two Condemnations. By such tribunals Galileo was twice condemned, first in February, 1616, and later in June, 1633. He was condemned in each case because of his adhesion to the Copernican system of astronomy. It would be more exact to state that in 1616 the Copernican theory was condemned rather than the man Galileo; and that in 1633 Galileo was sentenced partly for holding the condemned doctrine and partly for disobedience to a promise exacted from him by the Church.

THE FIRST CONDEMNATION.

In the first of the two years mentioned, there was question of the astronomical system founded by Copernicus, a Catholic ecclesiastic. For years this system had remained immune from censure, and would have continued to do so had not scriptural considerations been introduced. Physical science, as such, was outside the Church's province, but brought into relation with the Scriptures, of which the Church was the lawful interpreter, it awakened her interest. A letter of Galileo to his pupil Castelli, a Benedictine monk, attempting to reconcile Scripture with the Copernican system, inaugurated the conflict. This letter, written December 21, 1613, was reported to the Congregation of the Index. The delay till February, 1616, proves that action was not taken in undue haste.

What was the exact decision of 1616, and from what body or bodies did it emanate? It is true that a committee of theologians appointed by the Inquisition pronounced the Copernican doctrine "absurd and formally heretical." But this report was not the decision of any Congregation; it merely formed the doctrinal basis of the practical action now to be taken.

Indeed, there was no formal doctrinal pronouncement made in 1616, nor was the Inquisition, as such, directly involved. For the moment the sentences passed were purely disciplinary and practical. Galileo was asked by Cardinal Bellarmine to promise not to hold, defend, or teach the Copernican doctrine. He gave promise in writing and apparently with complete willingness. He was not asked to abjure nor did he

suffer any penance or other punishment. A fortnight later he had an entirely friendly audience of three-quarters of an hour with Pope Paul V, and a few months after left Rome with good reputation and with no charge resting upon him. The martyrdom of Galileo, therefore, did not begin as early as the year 1616.

The Interdiction of Books. Less mild than the sentence passed on Galileo was the decree of the Congregation of the Index. Believing and even asserting the Copernican system to be "false and contrary to the Scriptures," the Congregation took up for censure certain books inculcating it. Even now no writing of Galileo's was censured, out of deference for the great astronomer. The only book prohibited outright and by name was one recently published by the Carmelite priest Toscarini, which aimed professedly to prove that the Copernican system is in agreement with the Sacred Scriptures. With it were prohibited in general terms all other books of the same tenor.

Only conditional censure was applied to Copernican books that avoided the Scriptural argument. Thus the original work of Copernicus himself, as well as one other named, was merely "suspended until it should be corrected." Four years later, the desired corrections were indicated, eight in number, qualifying the Copernican doctrine as an hypothesis instead of being an established truth.

It was clearly the mind of the Congregation, and this was never repealed in later utterances, that the opinion might be broached as an hypothesis and as a subject for discussion. Its harmony with the Scrip-

tures might not, however, be defended. Perhaps there was inconsistency here, but the distinction was sincerely if illogically made. With a scientific system as such the Congregation did not care to meddle, but it asserted its right to decide on the correct interpretation of the Scriptures.

This decree of the Index will impress us differently according as we view it in its genesis or in its consequences. In its origin the decree was not unnatural nor, we may say, unwarranted. Copernicanism was still but a theory, as astronomers now agree. Most scientists of the time were against it. Against it were quoted certain Scriptural texts, then interpreted literally. The Congregation, therefore, thought to follow the best science of the time, both physical and scriptural, by opposing in a measure the Copernican teachings. Though in error, it was certainly not consciously opposed to the onward march of Science. Indeed, it thought to allow for future developments by permitting the teaching of Copernicanism as an hypothesis.

The event proved, however, that the action had not been of the wisest. The distinction between "hypothetically possible" and "contrary to the Scriptures" was beyond the reach of the average mind, and appeared, in fact, to involve a contradiction. So it came to pass that the generality of men remembered only that the theory had been condemned as "false and contrary to the Scriptures." In course of time, two other books were placed upon the Index, Kepler's "Epitome of the Copernican Astronomy," in 1620 or thereabouts, and Galileo's "Dialogue," in 1633. The effect of these edicts in restraining Catholics

from embracing Copernican views, remained in full force for about a hundred years. The nominal prohibition of the condemned books lasted for a hundred years longer.

Appreciation of the Decree. In forming a judgment of these decisions of the Congregation of the Index, we must remember that its action was not doctrinal but disciplinary. Of like character is every decision of this Congregation, merely regulating the conduct of the faithful in the matter of books and reading. If the effects were unfortunate for a certain system of science now admitted to be true, this was beyond both the intention of the Congregation and its power of foresight. Indeed, the Congregation thought it had made ample provision against such unhappy consequences by permitting the Copernican system to be taught as an hypothesis. It underestimated the effective influence of the words it had used in proscribing Copernicanism as "false and contrary to the Scriptures."

THE SECOND CONDEMNATION.

From these first decisions we now pass to the later decrees bearing on the case, those of the year 1633. They are more likely to arouse the sympathy of the reader, for they involve immediately the person and fortunes of the great astronomer. Whereas in the first pronouncement sentence had been passed upon a doctrine, in the second, as will be seen, the sentence bore directly upon an individual.

Change of Officials. Meantime certain changes of officials had occurred that were not without influence

on the ultimate result. In the year 1621 there died three persons of exalted rank: Pope Paul V, who had helped procure the first decrees though he had not signed them; Cosmo II, Grand Duke of Tuscany, the staunch friend of Galileo, his political subject; and Cardinal Bellarmine, who had been actively concerned in the first action taken, though by no means the "terrible opponent" that Andrew D. White describes.

Bellarmine was a man of seventy-four when the first decree was issued. Schooled in the science of Aristotle and Ptolemy, he was not likely at his great age to accept what appeared to him revolutionary doctrines. Undoubtedly he was instrumental in procuring the Index decrees of 1616, for he believed sincerely that the Copernican opinion was "false and contrary to the Scriptures." But he sought no persecution of Galileo. On the contrary, he defended him from the calumnies that were being circulated by giving him in May, 1616, a signed declaration. This declaration, to which Galileo appealed in his trial, was to the effect that Galileo had not been asked to abjure or to do penance, but had been informed of the decision prohibiting future defence of the Copernican doctrine.

Andrew D. White's description of Bellarmine as "the most terrible opponent" of Galileo is one of his many rhetorical exaggerations. All should know that Bellarmine had no share in the transactions of 1633, for his decease had occurred twelve years earlier. With him, however, did not die the race of ardent Aristotelians and Ptolemaists.

Cosmo II was succeeded as Duke of Tuscany by his son, Ferdinand II, who became Galileo's most

influential patron and friend. Pope Paul V was succeeded by Gregory XV, who reigned, however, but two years, when there came to the papal throne in 1623 Cardinal Barberini under the name of Urban VIII. Patron of art and learning and an energetic ruler, this prelate was destined to outlive Galileo, and was therefore the pontiff under whom the scientist was condemned and made to spend his last years in nominal imprisonment.

Pope Urban VIII. The accession of Urban VIII was a potent factor in shaping Gallieo's conduct. The new Pope, when cardinal, had befriended him in a dozen different ways. As early as 1611 he had displayed great interest in his telescopic discoveries. He had probably assisted in saving Galileo's person and his writings in 1616. A few years later he had written verses in his honor. To the new Pope Galileo dedicated a volume just finished, "The Assayer." The Holy Father accepted the dedication and expressed himself as delighted with the work.

He now showed his esteem for the astronomer by vouchsafing him six audiences in quick succession in 1624. One topic of their conversation was the Copernican system, of whose truth, however, Galileo failed to convince the pontiff. The latter conferred on the astronomer at his departure many favors and presents, as well as a pension for his son. Just after, in June, 1624, Urban wrote to the Grand Duke of Tuscany, praising the learning and piety of Galileo. Be it remarked here that the recipient of these pontifical favors remained all his life a devout and sincere Catholic.

Galileo's Blunder. The distinguished scholar, however, presumed too far on the favor of the Sovereign Pontiff. Inattentive to his solemn promise of 1616, he re-entered the dangerous field of Copernican discussion. He spent the next six years in composing a book, The Dialogue of the Two Systems, not the greatest of his works but the most celebrated because it occasioned his downfall. In it he presented both sides of the argument, but seemed to betray a very strong preference for the Copernican position.

In 1630 he was again at Rome, seeking now an imprimatur for his book. The Pope again received him and doubled the pension of his son. The story of the next two years is that of Galileo's effort to gain official sanction for "The Dialogue." At Florence he succeeded wholly, at Rome only in part. When the work appeared, he dared to insert the imprimatur both of Florence and of Rome, thereby offending Fr. Riccardi, the examiner at Rome, a former pupil and devoted friend.

The work, apparently avowing Copernican views, aroused excitement and even fury. The Holy Father was angered at this breach of confidence and of discipline. In September, 1632, he committed the volume for examination to a special commission. They reported that Galileo was guilty both of violating his personal promise and of upholding a doctrine condemned by the Church.

The Trial of Galileo. The author was summoned to Rome. Procrastinating, he delayed answering the summons from October, 1632, to February, 1633. Let these four months be set against the subsequent four in which too zealous sympathizers complain that

he was kept waiting for the final verdict. There is no indication that the verdict was purposely delayed to incommode the accused astronomer.

During all this period, moreover, the defendant was comfortably quartered, not kept in the dungeons of the Inquisition, as exaggeration would have it. Most of the time was passed in the house of Niccolini, the Tuscan ambassador, his staunchest supporter at Rome. Only twenty-two days were spent in the palace of the Inquisition, and these not in a prison, but in a suite of three fine rooms, with the attendance of Galileo's own body servant, and with frequent visits from the Tuscan ambassador and ambassadress.

Four interrogatories or hearings were given the accused by the Inquisition from April 12 to June 21. Galileo's defence was a denial of the charges. He protested that he had not broken his engagement, and appealed for the terms of that engagement to Bellarmine's Declaration. He claimed that in his Dialogue he had not designedly shown preference for the Copernican system, but had meant to present both systems with equal force. Finally, at the last hearing he reiterated again and again, even under threat of torture, that interiorly he did not hold to the Copernican system, but since the decree of 1616 had always believed the Ptolemaic system to be true.

The Sentencing of Galileo. Notwithstanding his disclaimers, the Inquisition found him guilty of the twofold charge, of having broken his agreement and of having taught Copernicanism, a forbidden doctrine. The climax came with the pronouncement of the sentence June 22, 1633. He was declared "vehemently suspected of heresy," was ordered to abjure

the Copernican doctrine, and was condemned to imprisonment and also to a penance, the recitation of the Penitential Psalms once a week for three years. The decree of the Inquisition, very solemn in its form, but in substance just as given above, was signed by seven of the ten cardinals composing the Congregation.

The same day Galileo was made on bended knees to pronounce and sign his abjuration. He was made to say that he "abjured, cursed and abhorred" the doctrine that the sun is stationary and that the earth revolves about it. The solemnity of the form of abjuration is discounted somewhat when we learn that it belonged to the legal phraseology of the time. But the dramatic pathos of the incident remains. An aged scientist on bended knees forswearing a belief to which all his scientific studies inclined him, in presence of the supreme court of the Church, is a spectacle that has never ceased to elicit sympathy.

Later on, romancers added other details of their own invention to heighten the spectacular character of the episode. They fancied that the culprit had been subject to actual physical torture, which is contrary to all the evidence that we possess. They retailed with delight the story that on rising from his knees Galileo had protested defiantly, "And yet it moves." This interesting story is, however, a fabrication of comparatively recent date, traceable no farther back than 1761, more than a century and a quarter after the event in question.

Judgment of the Case. Such are the bare facts in the case, given without coloring. The impression they leave will vary with the temper of mind of the individual reader. It will be sympathy in one man,

indignation in another, and perhaps cold calculating indifference in a third.

We have no intention of attempting to justify completely the decision of the court. The underlying basis of the decree of 1633 was a doctrinal mistake. Nevertheless we hold it fair to submit as extenuating circumstances that Galileo had been technically guilty of legal faults, and that the court's decision in 1633 was rendered according to the law actually in force.

SINCERITY OF GALILEO.

In our minds as we have been perusing the history, there has arisen the further question, what were Galileo's interior convictions respecting Copernicanism at the moment of his abjuration? Was he coerced to perjure himself, or was he perfectly sincere?

The question is worthy of examination. For the renunciation of the Copernican system by Galileo is generally esteemed the most dishonorable episode in the entire history. It is commonly supposed, even by writers of authority, that at the moment of his abjuration Galileo was fully convinced of the truth of Copernicanism, and therefore committed perjury.

Galileo's Inward Belief. There is a minority opinion, however, of utmost interest in its bearing on the case, that the astronomer's act of abjuration was absolutely truthful and sincere. The reasons for this opinion are not without weight. In seeking to penetrate Galileo's innermost thoughts, we must evidently adopt the standpoint of the seventeenth century, not that of the twentieth. We must, in addition, consider the general character of Galileo's studies.

Copernicanism was, at the time, a novel doctrine, repudiated by the vast majority of the learned, theologians and scientists alike. Their opposition could scarcely have been without some effect on the mind of the Florentine astronomer. In physics and mathematics, indeed, which were his specialty, there is little doubt that his opinions were proof against all such adverse criticism. But in astronomy the case was somewhat different. The proofs of the Copernican theory were incapable of being tested in the laboratory. The arguments in its favor were not as yet above reproach.

Noteworthy is it also that Galileo did not become a public advocate of Copernicanism till comparatively late in life. It was his telescopic discoveries of the years 1609 and 1610 that won him to the cause. On the basis of the facts they supplied, he wrote his first book in defence of the novel doctrine in 1613, when he was almost fifty years of age. Even then, with his fine powers of logic, he must have discerned that the arguments were not conclusive but only probable. On the scientific side, then, while he leaned strongly to the Copernican system, he could not establish it with certitude as he could, for example, his laws of falling bodies.

His Respect for Superiors. Combine with this now the fact of Galileo's profound respect for his ecclesiastical superiors. He wrote in 1614 that he would rather have an eye plucked out than resist his superiors by upholding against them the opinion of Copernicus. In the light of this statement, may we not believe that the mere teaching of the Church authorities sufficed at times to outweigh, in his estimation, even

the scientific arguments? Facts show that he sought in every way not to offend against the commands of the Roman tribunals. It is only when we remember how true a Catholic Galileo was, that we can measure the depth of the impression made upon him by the Church's official decisions.

On all these grounds we are inclined to believe that Galileo did not continue unremittingly attached to the Copernican system, but wavered from this side to that, swayed now by scientific reasons, now by the counsel and authority of his superiors. That a great scientist may thus waver in his views is proved by the parallel case of Buffon, the French naturalist of the eighteenth century, at first an anti-evolutionist, later an evolutionist, and in the end adopting a compromise opinion.

His Sincerity. If we can suppose such fluctuations in the mind of Galileo, then we can understand perfectly all his asseverations before the court of the Inquisition. He could say with utmost truthfulness that at that moment he repudiated the Copernican theory, bidden to do so by those for whose doctrinal decisions he had the highest respect. He could even aver conscientiously, after a vain endeavor to disentangle his conflicting emotions and opinions of the past, that from the time of the decree of 1616 he had always yielded his interior assent to that decision.

By such a judgment as we have ventured to suggest, the veracity of Galileo is rescued and made secure. Standing before the Inquisition, he is no perjurer, even technically or as the result of an extortion he could not resist, but he is still truthful in utterance and noble in deportment, without pride of mind

submitting his judgment to that of his superiors. Moreover, we thereby save the honor and dignity of the whole occasion. Neither Galileo nor his judges will appear to us hereafter as conscious hypocrites. The officers of the Inquisition, though convinced of his former guilt, believed him now sincere. Otherwise we cannot explain their final expression of approval, "Thou hast answered as a Catholic."

CHARACTER OF HIS IMPRISONMENT.

Galileo's Last Years. We now come to the final period of Galileo's life. In our analysis of it, we shall cling to the purpose we have maintained from the beginning, to consider only the official acts of the Church authorities, not the attacks and prejudices of private individuals. The acts of his personal enemies and antagonists may have been dictated by passion and malevolence. Not so the official decisions of the Roman Congregations. Their sentence, however fallible, rested on what the members conceived to be the demands of truth and justice.

We have stated that the Inquisition condemned Galileo to the punishment of imprisonment. But immediately a higher authority, the Holy Father, intervened, commuting the sentence into such a form that the imprisonment became only nominal. It is doubtful if Galileo spent a single day in the dungeons of the Inquisition. He was permitted to go at once to the house of his friend, the Tuscan ambassador.

After a fortnight, the place of his seclusion was changed by order of the Pope to the palace of the Archbishop of Siena, one of his most loyal friends

and admirers. In Siena, whose climate was more salubrious than that of Rome, he tarried some six months till about the close of the year 1633. But he panted for Florence and Tuscany, his native realm and the scene of his greatest triumphs. Permission was soon granted him to repair to his own villa at Arcetri near Florence, where he was destined to spend most of the remainder of his life.

Character of His Punishment. It is true that he was still held to a determined place of residence, obliged to live in comparative seclusion and forbidden perfect liberty of movement. His heart's desire to enter Florence was not gratified till 1638, when he had become completely blind and needed to be nearer the expert oculists of the city. Moreover, whether at Arcetri or Florence, he was not permitted to invite his friends, or to receive them in such numbers as might appear to constitute a class assembled for instruction. But, barring these restrictions, his liberty was well-nigh complete.

With him lived his son Vincenzo, and in his declining years several of his favorite disciples, Fr. Castelli, Viviani, and Torricelli. Not far away there dwelt in a convent his two daughters, Franciscan nuns, whom he could visit at will. One of these daughters Sister Maria Celeste, his dearest consolation, took upon herself his penance of prayer, but did not live to complete it. Nor was his companionship limited to those just mentioned. He was quite free to receive his relatives and friends, and even admiring strangers like Milton, the English poet, who visited him at Arcetri in 1637. His seclusion from the world, therefore, was far from being absolute.

Intellectual Activity. It is commonly supposed by men of superficial knowledge of the case, that Galileo's life was one of extreme sadness after the decree of the Inquisition had been pronounced. There is only a fragment of truth in this belief. Galileo must indeed have felt, at times most keenly, the disgrace of his condemnation, all the more that he was so devoted a child of the Church. But, whatever his feelings, there never escaped from his pen or lips, as far as we know, a single word of protestation that Rome had acted cruelly or that he had been the victim of injustice. In a very few instances he wrote with sadness in private letters of the unjust attacks made by his enemies and antagonists. But these animadversions are rare in his extant writings, and were never once directed against the tribunals or officials of the Church.

Finally, we should have expected to learn that after the condemnation Galileo was a crushed man and that his intellectual activity must then have practically ceased. So far from the truth is this that his greatest literary work and monument was composed in the period we are now considering. His observational and mental activity remained as of yore. In 1637 he discovered with the telescope the libration of the Moon. In the following year he brought out his greatest book, the Dialogue of the New Sciences, in which, as he himself describes it, he summed up the best results of his lifework in science.

To the last he was busy instructing his little knot of favorite disciples, suggesting the plan of the pendulum clock when his end was almost at hand. His scientific career during his last nine years proves

abundantly that his mind was calm and tranquil, and that he had accepted with admirable resignation the adverse decisions of the court of Rome.

Death and Burial. He died in February, 1642, fortified with the last sacraments of the Church and with the special benediction of Pope Urban VIII. His remains were at first interred in an obscure chapel of the Church of Santa Croce at Florence. Enthusiastic friends would fain have raised a monument to his memory, but this the Pope forbade, deeming it imprudent thus to honor a man who had been officially condemned.

Later, more tolerant counsels prevailed, his body was moved to a nobler resting place in the Church of Santa Croce, and above the sepulchre was reared with ecclesiastical approval a monument in stone. Inscribed on its front we read a glowing tribute to the memory of the distinguished scientist, "Galileo Galilei, Greatest Restorer of Geometry, Astronomy, Philosophy, Comparable to No Man of His Age."

CHAPTER XX.

RECENT CATHOLIC ASTRONOMERS.

In the progress that astronomy has made since the time of Galileo, Catholics have had an honorable share. The extent of their achievements is hard even for the scholar to determine. For nearly all our ordinary books of reference dealing with the history of astronomy, neglect almost entirely the religious beliefs of the world's chief scientists. Not the least service of the Catholic Encyclopedia will be to make known to English readers the goodly list of Catholics who have done notable work in astronomy and in other departments of learning. Uncertainty about this or that scientist's religious profession will disappear in the light of its authoritative and ably-written articles.

After Galileo. Already we know enough to affirm that the condemnation of Galileo did not diminish or discourage the study of the astral science by the children of the Church. The great Florentine had pointed the way. He had discovered a new inlet that led into a previously unknown continent. Into this channel so rich in promise there entered a multitude of navigators of every nationality and of many religious persuasions. The different nationalities of the quartette of astronomers pre-eminent in the seventeenth century give an excellent example of the cosmopolitan character of the science. For Galileo

himself was an Italian, Kepler a German, Huyghens a Hollander, and Newton an Englishman.

In the second and lower ranks was at work a small army of investigators, among whom might be found a large number representing the Latin races and the Catholic faith. Vacandard's article on the condemnation of Galileo enumerates over a dozen Italians who in this period contributed notably to the advance of mathematics and astronomy. Almost half of those named belonged to the Society of Jesus, an order which from Fr. Clavius down to the present moment has never failed to produce a respectable quota of industrious and successful laborers in this field. In general it is to be noted that Vacandard's list includes only those who studied and taught under the direct supervision of the Church, at the papal universities of Rome and Bologna.

CASSINI.

Domenico Cassini. Conspicuous in the list is one but little known to English readers, but so eminent in his profession as to deserve mention just after the illustrious quartette named above. We single him out for special study advisedly. Better is it to contemplate in leisurely fashion one noble figure such as his than to heap together a long list of foreign-sounding names that would be forgotten as soon as read.

The name of Cassini deserves not to be forgotten, nor will it be so long as any are found interested in the peaceful triumphs of the past. It is a name that continued to adorn the records of astronomy for four generations and for well-nigh two centuries. Father,

son, grandson and great-grandson, all served France at the Paris Observatory, the first, second and fourth as its chief director. It is the founder of this dynasty of distinguished savants who claims our attention here.

Giovanni Domenico Cassini, for such was his full name, was born near Nice, then Italian soil, in 1625 and died at Paris in 1712. His long life of eighty-seven years was dedicated chiefly to astronomy. Not a priest, he was yet a man of profound religious belief and of devout habits, teaching for years under the direct patronage of the Popes at Rome and Bologna, and later ceded by the Holy Father to France with utmost reluctance. He had been schooled by the Jesuits at Genoa. In his middle years he wrote and sent to the Jesuit, Fr. Riccioli, a treatise on the Immaculate Conception, and in his last year when he had been stricken totally blind he found in religion his chief consolation. Many Jesuit fathers, moreover, were taught astronomy by him who were afterwards to labor on the Chinese Mission.

Two Periods in His Life. The first half of his life was spent in Italy, the second in France. Loaned to Louis XIV by the Pope in 1669 when he had just reached middle age, he became attached to the soil of France, was soon naturalized as a citizen there and married a French woman, by whom he had a son, the first in a long line of worthy descendants. His interest in astronomy dated from early youth. Already at nineteen he had become instructor at Bologna, where he was destined to abide for twenty-five years, for most of that period as chief professor of astronomy.

By the year 1669 his fame had reached the ears of the French court, chiefly through the report of the Abbé Picard, then professor of astronomy at the Collège de France. He was permitted by the Holy Father to retire from Italy for a time, though the latter was loath to part with his services even temporarily. Cassini had been of real help to the Holy See by reason of his knowledge of both civil and military engineering, for his talent was versatile. Arrived in France, he prolonged his stay indefinitely and gave to the realm of Louis Quatorze the last forty-three years of his life.

Astronomical Achievements. In both countries he did astronomical work of brilliant character. As will be seen from the appended summary, his labors were chiefly observational. The telescope, reinvented by Galileo, had now been much perfected, and some of the very finest instruments, made by Campani of Rome, were placed in Cassini's hands.

His first literary production was a treatise on the comet of 1652. Soon there followed a series of discoveries in planetary astronomy of the first importance. It may be remembered from a former article of this series that one proof for the rotation of our earth is found in the axial movement of the sun and the planets. It is to Cassini that the world owes the first discovery of this important set of truths.

In 1665 he perceived the rotation of Jupiter, fixing its period at 9 hrs., 56 mins. Incidently he observed in that year, first of men, the transit of a satellite across the face of the planet. A year later he found that Mars was rotating with a period of 24 hrs., 40 mins. He was the first also to observe the white polar caps

of the ruddy planet. The rotation or libration of Venus, he could not define which, was determined by him in the following year as occurring once in every 23 hrs. Later, in 1678, when he had changed his residence to Paris, he was able to detect the sun's rotation on its axis in a period of 25.58 days. Cassini was, therefore, the pioneer in the study of solar and planetary rotations, and his calculations remain even now almost mathematically correct.

His Achievements at Paris. Soon after going to Paris, between the years 1670 and 1672, he observed and studied the New Star which had blazed forth temporarily in the constellation Cygnus and which had been first sighted by a Carthusian monk of Dijon, Fr. Anthelme. About the same time he made in collaboration with Richer the first scientific determination of the sun's distance, fixing it at eighty-seven millions of miles, which we know now to be some six million miles short of the reality.

Again let it be remarked, however, that it was in the field of planetary astronomy that his finest victories were won. He will be longest remembered for having added a group of four Saturnian satellites to the one discovered by Huyghens. These "finds," occurring between 1671 and 1684, would have been impossible without the splendid instruments he had received from Campani of Rome. Meantime, in 1675 or 1676, he enlarged further our knowledge of the planet Saturn, by distinguishing two rings in the annular body surrounding the planet, instead of the single ring observed already by Galileo and Huyghens.

We might continue on thus for some paragraphs enumerating the successful investigations of this

great astronomer. His studies on atmospheric refraction, on the Jovian system of satellites and the determination of a meridian arc, all important, would require each a section for its proper elucidation. Of his pioneer work on the Zodiacal Light, pursued from 1683 to 1688, Todd of Amherst has written that "he had established its form and position so critically that no observations at the present day would appear to indicate any change."

A Catholic Astronomer. Enough has been said to prove that we are here dealing with an astronomer of almost, if not quite, the first rank. Cassini is quoted again and again in current text books of astronomy. In the temple of the world's greatest scientists there is a niche reserved for him. That with love of science he combined sincere love for religious truth is proof that there is no incompatibility between the two. That his career unfolded itself in the years just following Galileo's condemnation, under the auspices and favor of the Church of Rome, is proof that the Catholic Church is not opposed to the proper advance of Science.

FR. PIAZZI.

The Eighteenth Century. After Cassini came the eighteenth century with its race of giant mathematicians, chiefly French, whose triumph it was to apply Newton's law of gravitation successively to all the individual bodies of the solar system. So firmly did they intrench this all pervading law that thereafter it had nothing to fear from hostile criticism.

In this period as in the preceding occur Catholic names garlanded with honor. True, its first honors

are by common consent awarded to two who were outside the Catholic pale, Herschel of England and Laplace of France. But only just behind in celebrity come a fair number of loyal Catholics, among them the Jesuits, Frs. Boscowich and Mayer. Of peculiar interest and of more than ordinary claim to our attention is the career of Fr. Piazzi, an Italian priest of the Theatine order, who on the night that ushered in the nineteenth century discovered the first of the minor planets.

Discovery of Ceres. The discovery of the little planet Ceres was one of the many incidents that make the history of astronomy so fascinating. It was one of the succession of surprises that followed Galileo's invention of the telescope. As events proved, it was the first in a train of similar revelations, for when the first minor planet had been found, the way was opened for a long series of similar disclosures reaching to the present moment and not yet at an end.

Ceres is the type of an entire class of celestial objects known indifferently as minor planets, planetoids, or asteroids, of a new species and rank, different from the many species hitherto catalogued. Sun and moon, planets and stars, had been known to men from time immemorial. Comets and meteors were transient objects almost equally well known. Recently the telescope had revealed nebulae distinct from the stars and many new moons or satellites attached to the various planets. But now under Fr. Piazzi's hand, this powerful instrument caused the firmament to yield up other secrets, tiny jewels daintily set by the Great Artificer in the casket of the heavens.

Preparation for the Discovery. The story of the finding of Ceres runs in some four sections or para-

graphs and brings one back a century or two in astronomical history. As early as the year 1600 or thereabouts, Kepler had conjectured that there might be an undiscovered planet in the space that intervened between Mars and Jupiter. The suggestion was almost heresy at the time, for a certain sacredness was attributed to the number seven as applied to the planetary group. Heretical or not, Kepler advanced the view of a new planet, unable otherwise to account for the disproportionate distance between Mars and Jupiter.

In the next century, two astronomers named Titius and Bode confirmed the likelihood of the existence of Kepler's supposed planet by working out, as they believed, the law of distances according to which the planets are arranged in the solar system. This law, first formulated in 1772, is sometimes called the Law of Titius, sometimes the Law of Bode. It says that the planets, Mercury, Venus and the rest, are separated from the sun by distances that increase in regular arithmetical progression.

It gives a set of figures simply related, expressing approximately the distances of all the planets. By adding 4 in turn to the numbers 0, 3, 6, 12, 24, 48, 96, etc., we obtain the series in question. The figures obtained, viz. 4, 7, 10, 16, 28, 52, 100, etc., are found to be in the same ratio as the solar distances of Mercury, Venus, Earth, and Mars, and skipping the figure 28, the higher numbers 52 and 100 apply quite well to Jupiter and Saturn.

Indeed, when Herschel in 1781 discovered the great planet Uranus, it was found to fall under the number 196, the next higher number demanded by Bode's

Law. This cumulative testimony made it seem probable that there must be as yet unseen a member of the group of planets in the space between Mars and Jupiter, at the post indicated by the number 28. Kepler's conjecture had found reinforcement in the Law of Titius or Bode.

Search for the Planet. There ensued then a search for the suspected planet, led by Von Zach of Germany, pursued faithfully by him for fifteen years beginning in 1785, and finally organized by the same astronomer by dividing the Zodiac into six equal parts each assigned to a chosen observer, one of his band of "celestial police." But, strange to say, the organization had scarcely gotten well to work when announcement came from another quarter of the discovery for which they had been planning.

To Fr. Piazzi, a Theatine priest laboring in Sicily, fell the honor which Von Zach had sought. This priest was at the moment diligently employed in completing a catalogue of the stars begun ten years before. On the opening night of the nineteenth century, January 1, 1801, he descried a new object in the Zodiac which after six weeks of watching he determined to be neither comet nor star, but a veritable planet with an independent motion around the sun as a focal centre. With the single exception of Herschel's finding of Uranus in 1781, it was the first discovery of a planet since the most ancient times.

Piazzi at once communicated the news of his success to the astronomers of Milan and Berlin. The planet was soon lost to view merged in the rays of the sun. But it was rediscovered by Von Zach himself just a year later, on the night of January 1, 1802.

In Piazzi's honor and at his request, the name Ceres was bestowed on the new planet, this being the name of the ancient pagan goddess of the fertile island of Sicily. In subsequent years some five hundred other planetoids have been detected floating in the zone of space between Mars and Jupiter.

Piazzi's General Career. Piazzi's discovery of the first minor planet, though partly accidental, was yet the just reward of a worthy career spent almost entirely in the service of astronomy. Born in Italy in 1746, he had entered at the age of eighteen the Theatine order of priests founded by St. Cajetan early in the sixteenth century. After teaching for a time in Italy and Malta, he became professor of mathematics at the University of Palermo in 1780. Here the Viceroy of Sicily befriended him, building for him a fine observatory in 1791.

Meantime, from 1786 to 1789, Piazzi was perfecting himself in astronomy under Lalande at Paris and Maskelyne at Greenwich. From England he brought back to Sicily a five-foot circle for measurement, the largest and finest instrument of its kind then known. It had been built at his express order by Ramsden of England. Equipped now with proper instruments, he entered upon expert observational work that continued for several decades, terminated only by his death in 1826.

Particular Achievements. Besides his finding of the new planet, Piazzi is honorably remembered for his researches in stellar astronomy. From 1791 forward, he was engaged upon a catalogue of the stars which, when finally published in 1803 and 1814, was acknowledged to be the best that had appeared.

Embracing almost 8000 stars, it was constructed on a plan that was then regarded as a model.

A particularly interesting bit of observational work was his discovery in 1792 of the proper motion of the star numbered 61 Cygni. It was among the first demonstrations of the movement of a star among its fellows. The amount of this star's motion as seen from the earth is but five and two-tenths seconds of arc a year. In a thousand years it will have moved from its first position about three times the breath of the moon. Small in itself, this speed is very large as stellar motions go, and ever since Piazzi's time, 61 Cygni has been known as the Flying Star.

Numerous other achievements also marked the career of this faithful priest-astronomer, but none so noteworthy as those just enumerated. They are sufficient to have won him a place of honor in astronomical history. His name will forever be associated with the discovery of Ceres, the first asteroid. His example is, however, but one among many of Catholic priests who in all the centuries have found delight in the study of the heavens.

CHAPTER XXI.

FR. ANGELO SECCHI, S.J.

"One of the glories of Italy," such was the encomium paid Fr. Secchi by one of his fellow Italian astronomers shortly after his death in 1878. Similar eulogies were sounded in France, Belgium and England. The whole world, irrespective of nationality or creed, united in mourning his loss and in testifying the most sincere respect for his memory.

Nor had Secchi to wait till death for a recognition of his merits. Happily in his case the world rendered justice while he was yet alive. Marks of esteem came to him from every side, and from sources otherwise widely divergent, from princes of the Church and rulers of states, from the papal government and from emperors, as well as from scientists and scientific bodies in every civilized country.

He was a member of the scientific associations of London, Paris, Brussels and Berlin, of St. Petersburg, Madrid, Philadelphia and Rio Janeiro, as well as of numerous Italian societies. Napoleon III gave him the cross of the Legion of Honor, and the Emperor of Brazil made him a dignitary of the Order of the Golden Rose. Moreover, throughout his life he enjoyed the favor and patronage of Pope Pius IX. Extraordinary must have been the gifts and exceptional the achievements of the man who could count so many distinguished and eminent admirers.

Secchi's Early Years. The birthplace of Fr. Secchi was the town of Reggio in Northern Italy, and his birth-year was 1818. He had completed almost sixty years, therefore, when he succumbed to disease in 1878. Educated by the Jesuits, he entered their order at the age of 15, and already in his teaching as a young scholastic betrayed his love and talent for the physical sciences. Expelled from Italy with others of his order in 1847, he was ordained priest at Stonyhurst in England.

It is very interesting for us Americans to learn that he spent the first two years of his priesthood in the United States, teaching at Georgetown College. There he did his first work in astronomy, became enamored of the science, and consecrated to it thenceforth the best of his powers. At Georgetown, too, he published his first work, on some electrical subject, if we remember aright, issued under the auspices of the Smithsonian Institution.

When in the year 1849 Fr. de Vico died, Secchi was appointed his successor as director of the observatory of the Roman College. The latter is not to be confounded with the Vatican Observatory which is under the immediate authority of the Pope. Both are, however, pontifical observatories, and at the present moment, as it happens, both are directed by Jesuit Fathers, Fr. Hagen, formerly of Georgetown, being now at the head of the Vatican Observatory. Secchi's post was the charge of the similar establishment conducted by the Jesuit Order, and connected with their Roman or Gregorian university. Thither he repaired from Georgetown in 1850 or thereabouts, and there he spent all his remaining years engrossed

in scientific labors, of whose results he has left humanity the fullest possible account.

Director of the Roman Observatory. His first task after assuming the directorship was to relocate and re-equip the observatory. On the summit of the Church of St. Ignatius at Rome, with its powerful foundations, he found the rooms and built the towers and domes for housing his instruments. To the six-inch telescope already in possession, he added a splendid nine-inch Merz refractor and a sidereal clock, as well as many magnetic and meteorological instruments. When in 1859 the principle of the spectroscope was discovered by Kirchhoff, he at once adjusted this instrument to his telescopes and became one of the world's foremost authorities in the science of spectrum analysis.

That he was able to compass these improvements was due in great part to the munificence of Pope Pius IX. The Pontifical government was especially interested in his meteorological work, and in labors that made for the safety and convenience of the people. The first time-ball signaling the noon hour was established at Rome by Secchi at the instance of the Holy Father. On one occasion he was missioned to inspect the lighthouses in the pontifical states.

The edifice constructed by Secchi was of particular value to the government because it combined in one a well equipped weather bureau and an astronomical observatory. Herein was placed, for example, the most remarkable of Secchi's inventions, a complex instrument for recording automatically and simultaneously the temperature, the barometric pressure, the humidity, the rainfall, and the direction and

velocity of the wind. This ingenious device, named by Secchi the meteorograph, was exhibited at the Paris Exposition of 1867, and was awarded a prize of $20,000.

Stellar Astronomy. It is impossible within our narrow limits to give even a fair idea of Fr. Secchi's manifold astronomical discoveries. Leaving all else aside, we must content ourselves with a brief development of two of his more noteworthy achievements, bearing respectively on the stars and on the sun. In the field of sidereal astronomy he had begun in the first decade of his administration a particular and original study of double stars and nebulae. The second decade witnessed his application of spectroscopy to a great multitude of stars. The results were of surpassing interest and are still widely quoted.

According to Miss Clerke, it was Fr. Secchi who in 1862 began the first spectroscopic survey of the heavens. He took for examination some four thousand stars. These he catalogued in four distinct classes, characterized by four spectral types, the members of each class being similarly composed.

In the first class were Sirius, Vega and all other whitish stars, more than one-half the entire number, characterized by an abundance of the element hydrogen. In the second class were yellowish stars of the type of Capella and the Sun, almost as numerous and exhibiting the presence of the metals in goodly quantity. In the third were placed the reddish stars, as Betelgeux and Antares, and the variables, as Mira, giving the spectrum of the metalloids. Finally there were a few ruby-colored, "like drops of blood," whose basis was the spectrum of carbon. Thus did

Secchi explore those distant orbs trillions of miles away, and by bringing them into his laboratory, as it were, oblige them to declare the elements of which they were composed.

Solar Astronomy. Even more renowned are Secchi's contributions to the science of the sun. For almost thirty years he continued his observations of this greatest of the lights of heaven, investigating all its separate phenomena with unsurpassed and perhaps unequalled assiduity and success. Solar eclipses and sun spots, the sun's chemical make-up and temperature and rotation, the faculae, the chromosphere with its hydrogen flames, and the corona, all of these were the objects of his study. Familiar with all that his predecessors and contemporaries had learned touching the solar orb, by his own personal researches he augmented and enriched this particular chapter of astronomy in every single detail.

Present at a total solar eclipse in Spain in 1860, he secured the first photographs ever taken of the sun's outer appendages, its hydrogen flames and its corona. Later, when Jannsen had discovered the means of securing even in broad daylight spectra of these flames and of the chromosphere, Secchi was among the first, as he became among the most assiduous, in applying the new method. One other solar eclipse was witnessed by him in 1870, but, as he himself confesses, with less happy results, owing to sinister atmospheric conditions.

On sun spots, their number, size and ever-changing phenomena, he became from long experience a world-renowned authority. With Faye, one of the most eminent of the French astronomers, he disputed

ardently the question of the origin of sun spots, attributing them to solar volcanic eruptions and denying Faye's theory of solar cyclones or whirlwinds.

His Literary Productions. Even the unlearned in these branches will now appreciate somewhat the marvellous character of Secchi's studies relative to the sun. To investigate at a distance of ninety-three million miles this luminous body hung in space, at that forbidding distance to determine its degree of heat and its material composition, to penetrate the mysteries of its physical life by interpreting the many phases of activity it displayed, such were Fr. Secchi's crowning accomplishments. Among his numerous literary productions, his book entitled Le Soleil, for it was written in French, is on all hands acknowledged to be his masterpiece. First printed in 1870, then enlarged and published in a magnificent edition of two volumes in 1875–7, it is regarded as one of the greatest astronomical works of the century.

He published, besides, a half dozen other volumes, the latest a work on the Stars, completed and issued in his dying year. His minor works, memoirs, monographs and essays, issued from his hands at the average rate of one a fortnight, for the space of twenty-seven years. The catalogue of his complete works includes close to seven hundred titles.

Scholar and Religious. Thus indefatigable and thus productive was the immortal Fr. Secchi. He has taken his place among the greatest astronomers of the age. When after the triumph of Victor Emmanuel in 1870 the other Jesuits were expelled from Italy, Secchi, with a few attendants, was permitted to remain. So highly was his genius rated even by the civil powers.

But he remained forever true to his religious vows, as estimable in his private life as in his public accomplishments. Of all the eulogies rendered him, undoubtedly none would have given him greater pleasure than that of his distinguished patron and friend, Pope Pius IX: "Behold the true religious and the true Jesuit! So learned and so humble!"

LATER ASTRONOMERS.

The influence of Fr. Secchi, the Jesuit astronomer, has been widely felt throughout the Catholic world. Many members of his own order have followed in the footsteps of their distinguished predecessor, with such excellent results that the work of the Jesuit observatories scattered over the globe commands universal respect. Others also, outside the Jesuit order, have owed to Fr. Secchi the inspiration to devote their lives to astronomical and kindred studies.

Fr. Denza, Barnabite. Among the worthiest of his immediate pupils was Fr. Denza, a member of the Barnabite order of priests. The latter was, like his master, an Italian, and dedicated to his native country his entire life-service. He was born at Naples in 1834 and died at Rome in 1894. The major part of his manhood was spent at the Barnabite College of Moncalieri, near Florence. For thirty-four years, from 1856 to 1890, he taught there, specializing in meteorology.

The fame and influence of Fr. Denza reached far beyond the boundaries of his college. A monthly bulletin of meteorology, published continuously from 1859 till his death in 1894, made this humble and de-

vout priest known throughout the length and breadth of Italy. It was in imitation of the observatory at Moncalieri and through its direct influence that two hundred other weather bureaus were set up in various parts of Italy. In appreciation of his services, Denza was made President of the Italian Meteorological Society in 1881, and was continued in this office for many years.

Closely related with meteorology is the science of astronomy, for one is the physics of the atmosphere, the other the physics of the heavens. It was natural that Fr. Denza, like his preceptor Fr. Secchi, should combine in his studies these two branches of learning. His claim to mention in the present series of brief biographical memoirs, rests upon the emphasis he gave in his last years to the study of astronomy.

Embassies to France. Twice he was sent by the reigning Pontiff, Leo XIII, as a delegate to scientific congresses held in France. After the first of these, in 1884, he visited England and Holland, and was received in both countries with acclaim and honor. On the occasion of his second visit to France in 1887 he was able to accomplish a very notable stroke in favor of the interests he represented.

At this convention, the Paris Astronomical Congress of 1887, it was decided to undertake an international photographic survey of the heavens. All the stars down to the fourteenth magnitude inclusive were to be photographed and properly catalogued. It was a gigantic enterprise, and even now awaits its final accomplishment. The eighteen observatories among which the work was to be apportioned, must evidently be of the finest character from the viewpoint of suitability for this particular line of research.

It was in consequence of Fr. Denza's influence and in direct answer to his appeal, that the Vatican Observatory was included among the limited number marked with this signal honor. It must surely have been gratifying to the scholarly pontiff that such recognition was given to the astronomical observatory over which he had immediate jurisdiction.

The Vatican Observatory. The papal observatory, established years before, had been developed into a new institution under the fostering care of Leo XIII. He had given to it for its use the ancient Leonine Tower, situated within the precincts of the Vatican. He had moreover caused it to be equipped with proper instruments. These donations, coupled with a display of unflagging personal interest, did honor to the learned pontiff, and gave encouragement to the scientists appointed to carry on the observatory's work.

When the first director died in 1890, Fr. Denza was quite naturally chosen by the Holy Father for the succession. The new appointee remained in charge of the observatory's affairs till his demise in 1894. During his brief term of office he inaugurated successfully the Vatican's share in the great undertaking of photographing the entire heavens. At his death he was president of the Academia dei Nuovi Lincei. Author of several treatises, he bequeathed to posterity the example of a sincere love for learning, coupled with true devotion to his priestly calling.

Fr. Denza's successors at the Vatican Observatory illustrate the widespread interest of the different religious orders in the subject of astronomy. His immediate successor was Fr. Rodriguez, a Dominican, who occupied the post for twelve years. At his death

the charge was offered to Fr. George Searle, the Paulist, director of the observatory at the Catholic University in Washington. He declining the promotion, the office was conferred on Fr. Hagen, S.J. then stationed at the Georgetown Observatory.

This Jesuit father, a specialist in astronomy and author of several volumes of acknowledged value, will doubtless bring new fame and glory to his own religious order and to the observatory refounded by Leo XIII.

Miss Agnes M. Clerke. We cannot in justice terminate this series of memoirs, incomplete though it be, without some reference to the Irish Catholic lady whose name is written above. No one in modern times has written more beautifully on astronomical subjects than Miss Agnes M. Clerke. Such was the praise given her at the time of her death in 1907 by the most impartial critics. Though she had not been herself a practical astronomer to any considerable extent, she had nevertheless served the science so admirably with her pen as to win admission into the best of the British astronomical associations. She was one of four women who alone, in its long history of centuries, have been made Fellows of the Royal Astronomical Society.

The subject of this memoir was born in County Cork, Ireland, in 1842, and died at London in 1907. Educated privately, she received an excellent training in general literature and in music. As early as 1857 she evinced a more than common interest in astronomy, presaging her future career by beginning to write at that tender age a history of the science. After spending many years in study at Florence, Italy, she

returned to the British Isles in 1877 and settled at London. Her remaining thirty years were a period of remarkable literary activity, devoted almost exclusively to the exposition of astronomical subjects.

Her Literary Labors. Our space is too short to allow an adequate enumeration of her literary productions. She was a regular contributor to the Edinburgh Review, her "Copernicus in Italy" of the year 1877 being the first of a series of fifty-five articles from her pen accepted by that journal. Other periodicals, too, were enriched by her astronomical essays.

For the Dictionary of National Biography she wrote as many as one hundred biographies of famous scientists. If one has occasion to consult the well-known Encyclopedia Britannica, one will find many of its articles on the world's great astronomers, as Galileo, Kepler and Laplace, signed with her initials. Unfortunately she lived to write but one article for the Catholic Encyclopedia, that on Astronomy.

More important than this occasional work were the half dozen complete volumes, issued from 1885 on at fairly regular intervals. Of these we have space to mention only her History of Astronomy in the Nineteenth Century. This book, appearing first in 1885, established at once the reputation of its author. Brought constantly down to date in successive editions, it reached its final form in 1902. There exists no more authoritative or finer treatise on the subject of which it treats.

Science and Religion. In all of Miss Clerke's writing is found the same twofold characteristic of charming literary style and profound astronomical

knowledge. In her power of exposition she is admitted to have been almost, if not quite, unrivalled among recent authors of astronomical books. That her scientific attainments matched her literary gifts, her reception into the foremost of Britain's societies of science is a proof.

Fidelity to the faith of her childhood never suffered from her pursuit of scientific learning. She "acknowledged with supreme conviction the insufficiency of science to know and predict the possible acts of the Divine Power." Her memory will remain an example in the concrete of the perfect harmony between science and religion.

CHAPTER XXII.

THE NEBULAR HYPOTHESIS.

In every science there is a certain amount of speculation, as well as of information founded on ascertained truth. So is it with astronomy. The modern era has witnessed a marvellous increase in our positive knowledge respecting the heavenly bodies. The rotation and revolution of the earth, the superior magnitude of the sun, the universality of the force of gravitation, are no longer subjects for discussion. They and countless similar truths have been harvested from the field of speculation into the granary of well-established facts.

Knowledge, however, is fertile and generates constantly new subjects for speculation. The very settlement of ancient astronomical problems by modern science has started new problems that whet the mental appetite. Modern astronomy, like its ancient counterpart, has its own theories and speculations, attempts to penetrate farther into the unfathomable mystery of nature. Of these modern astronomical theories, the most important and interesting is the Nebular Hypothesis.

Its Purpose. This hypothesis is an attempt to explain the manner in which the solar system was formed. It has for its purpose to trace the history of the solar system from the beginning down to the

present time. The past history of the system dominated by the sun we cannot, it is true, know with certainty. There are no historical records to appeal to. We can only infer and conjecture. But that our conjecture may have weight, it must rest on the present disposition of the bodies of the solar system and on the constant laws of nature.

Such a conjecture is the Nebular Hypothesis, interesting because of the fundamental import of the problem it attempts to solve, and attractive because of the beauty of its solution. Of the truth of this theory we have not now to speak. Whether or not it portrays correctly the evolution of the solar system, we do not know for certain and perhaps shall never know in this mortal life. But all must admit that it is a conception of inherent beauty, leaving an indelible impression on the imagination. Whether we subscribe to it or not, we cannot deny it to be a bold and daring speculation, worthy of the men of genius who were its authors.

The Solar System. It will be our effort in this chapter to expose the Nebular Theory in outline, by describing the process through which according to its tenets the solar system has reached its present state of development. As a preliminary, it will be necessary to recall the present disposition of the bodies that are involved.

The solar system is composed chiefly of the sun, the planets and their satellites. Minor members, which for present purposes need not be heeded, are meteors, some comets and the zodiacal light. The principal planets are eight in number, named in order Mercury, Venus, Earth, Mars, Jupiter, Saturn,

Uranus and Neptune. Each of these, with the exception of the first two, is known to be accompanied by one or more moons or satellites. The number of these ancillary bodies varies from one for the Earth to ten for Saturn, and totals not far from twenty-five.

The nearest planet, Mercury, is at an average distance from the Sun of 36,000,000 miles; the most remote, Neptune, is separated from it by 2,800,000,000 miles. Of such enormous magnitudes are the spaces with which astronomy deals. Between Mercury and Neptune are situated the remaining planets with a fairly regular spacing. We have already told how the disproportionate gap between Mars and Jupiter led to the discovery of Ceres, the first of five hundred minor planets, distinguished from their better-known congeners only by inferiority of size.

The Central Body. All the planets, major and minor, revolve about a common centre, the sun. The sun is therefore the chief and parent of the system not only on account of its pre-eminent magnitude, for its mass is 750 times that of all the planets combined, but also because of its gravitational influence, which compels the planets to circle in their present orbits.

Is it the parent body in another and more literal sense, namely that the planets are but offshoots from it and were once incorporated in its mass? This is precisely what the Nebular Hypothesis affirms. That the sun, planets, and satellites, formed in the beginning but one body, that the planets have in course of time been detached from the sun, and the satellites in turn from the planets, this is the very essence of the Nebular Hypothesis.

It follows from the theory that the sun must have been at one time of far greater extent than now, stretching to the extreme boundaries of the present solar system, clear to Neptune's orbit, and compassing, therefore, a radius of 2,800,000,000 miles. In this original body were included all the elements and materials now divided between the sun, the planets and the satellites.

The Primitive Nebula. It is further supposed that this gigantic primeval body was heated to a degree of temperature beyond our power to imagine. An immense, fiery, incandescent mass, composed of glowing vapors and iridescent gases, such is the picture of the beginnings of the solar system as revealed by the Nebular Theory.

To one dwelling outside the sphere of solar influence, an occupant, let us say, of some far-distant world, the primitive sun might have appeared as do the nebulae at the present moment, not as a distinctly shining star, but as a cloudy mass of light of irregular outline and uneven lustre. The theory here discussed is called the Nebular Hypothesis, precisely because it supposes that the original sun was a nebulous body of irregular boundary and chaotic structure. A picture of a nebula, to be found in any good text-book of astronomy, will illustrate what the sun is supposed to have been in the remote past.

Does not this conception of the origin of our system accord fairly well with the description given by the Book of Genesis of the first primeval chaos? "In the beginning God created the heavens and the earth; and the earth was void and empty. And darkness

was upon the face of the deep. And the Spirit of God moved over the waters."

Long before the Nebular Hypothesis was broached by astronomers, the poet Milton had in his Paradise Lost limned a similar picture of the world's beginning. The passage begins,

"A dark, illimitable mass, without bound,
Without dimension, where length, breadth and height,
And time and place are lost. Where eldest night
And chaos, ancestors of Nature, hold
Eternal anarchy amid the noise
Of endless wars."

How like the modern postulate is the poet's noble concluding verse, "Some tumultuous cloud instinct with fire and nitre"!

Variations in the Hypothesis. We have dwelt thus long upon the original supposed condition of the solar system, because it is the very kernel of the Nebular Hypothesis, and the point of harmony among all the variations of this celebrated theory. In explaining the development of nature from this first chaos to its present well-ordered state, the different scientists part company. There are three astronomers in particular whose relation to the hypothesis it will be useful for us to consider.

PARTICULAR THEORIES.

Oftentimes the name "Kant-Laplace Theory" is given to the hypothesis we are now explaining. For its two chief founders were Kant, the German philosopher. and Laplace, the French mathematician. Both flourished in the closing decades of the eighteenth

century. Between them, however, we should insert the name of Sir William Herschel of England, a contemporary and no less illustrious advocate. To these three men and their respective expositions of the theory we now turn our attention.

The Order of the Solar System. To Immanuel Kant belongs the credit of having first conceived the Nebular Hypothesis. The order and harmony of movement of the several members of the solar system formed the basis of his reasoning. We have already described how the sun is attended by a colony of planets circling about it at different distances. We have now to recall that all the planets move about the sun with almost absolute uniformity.

All are revolving about the sun in practically the same plane, as so many ships on a level ocean. They keep true to that ocean level, never leaping up from it at an angle or sinking below its surface. The remotest planets follow the same plane as the nearest. When we consider the many possible planes in which the planets might have been set moving we see that their uniformity of orbit cannot be the result of chance or accident. The chances, says Sir Robert Ball, would be a million to one against it.

Moreover, all move about the sun in a common direction, from west to east, which is the direction also of the sun's own rotation. It is as if the sun were stretching out a great arm into space, forcing the dependent bodies to move in unison with itself. Each of the planets, too, rotates on its own axis, and all rotate in the same direction. The very satellites of the planets revolve and rotate in courses parallel with those of the larger bodies. It is this harmony of the

planetary motions, this "music of the spheres," that has excited the wonder and admiration of all thinking men since the time of Pythagoras, the ancient Greek philosopher.

Kant's Theory. It was this harmony of motion that Kant attempted to explain. One way of accounting for it, to be sure, was to refer it simply to the Fiat of the Creator. But might there not be another explanation? Might not the present admirable arrangement of the solar system be due to the operation of nature's laws? To say the latter needs not derogate from God's glory. Which is more admirable, to create a flower full-blown or to create the seed and breathe into it a power by which it shall afterwards evolve into trunk and stem and leaf and flower?

Kant, therefore, conceived that the present orderly arrangement of the universe is the outcome of a process of growth. He conceived a time in the distant past when sun and planets and satellites were all involved in a huge fiery mass. Forming then but one body, they would all participate in a common motion. Herein he detected the origin of the uniform motions that the planets now manifest. From this parent nebula were destined to be born the planets and their satellites. For some parts of the nebula, denser than others, would become centres of attraction around which considerable masses of matter might be aggregated.

By a law of physics, every body in the fluid state assumes the form of a sphere or globe. According to this law, the aggregations around attractive centres would have formed into globes, and in process of time a number of distinct spherical bodies would have

replaced the original chaotic mass. But even now these separate bodies, though independent and distinct, would retain the motion in a common direction originally imparted to them.

Thus by an appeal to the laws of nature did Kant explain the orderliness and uniformity of movement of the heavenly bodies. Expressed briefly, his argument says that all the components of the solar system have today a common movement because once they formed part of a common body endowed with a rotatory movement. Though separated now into smaller units, they still traverse space and circle on axes in obedience to the original impulse. Whether or not we assent to the theory of Immanuel Kant, we may at least acknowledge it to be a noble conception worthy of its author and not unworthy of the Creator whose visible works it seeks to explain.

Theory of Herschel. Next after Kant in advocacy of a nebular theory comes Sir Wm. Herschel. His views, arrived at on independent grounds, are a valuable confirmation of Kant's hypothesis. They will impress us the more if we remember that in the field of pure astronomy Herschel was more of an expert than Kant, and is rated, indeed, as one of the greatest astronomers of all time.

Herschel's reasoning in favor of a nebular theory rested, not as with Kant on the regularity of planetary movements, but on the various classes of nebulae and stars that dot the heavens. Pioneer in stellar astronomy, he had himself discerned some 2500 nebulae distinguished from the true stars by being spread out as milky or cloud-like masses of light. Among the nebulae he had discovered differences of size and of

degree of condensation, which suggested to him that they might be arranged in classes.

Some there were, to quote from Newcomb, "large, faint and diffused, in which a process of condensation seemed hardly to have begun. Then there were smaller and brighter nebulae which had been so far condensed that the central parts would soon begin to form into stars. There were yet others in which stars had actually begun to form. And finally there were star clusters in which the condensation was complete."

In these four classes of nebulae, Herschel seemed to read the history of the universe. Every nebula was on its way to become a star; every star had once been a nebula. He could even compare the ages of the nebulae from their degrees of condensation, just as from other signs we can compare the ages of the trees of a forest.

Application of His Theory. The nebular theory of Herschel may without straining be extended to the origin of the solar sytem. Indeed the application follows of necessity. For if all the stars have started from the condition of nebulae, then our sun, which is indubitably a star like all the others that sprinkle the sky, our sun, the nearest star, must have been itself at one time a nebula. When in the nebular state, it must have extended far beyond its present confines, including within its mass the materials of all the bodies now tributary to it.

Here, then, we have in outline the hypothesis of Sir Wm. Herschel. It is an even bolder and grander conception than Kant's, for it intimates not merely that our solar system is the offspring of a primitive

nebula, but that every star of the millions that exist has had a similar origin. Every sun was once, in the words of Milton, "a tumultuous cloud, instinct with fire and nitre."

CHAPTER XXIII.

THE THEORY OF LAPLACE.

In the year 1796, in a book entitled "Exposition of the System of the World," the Marquis de Laplace presented and explained his theory of the origin of the solar system. The authority of the French astronomer was so eminent and his reasoning for the theory so plausible, that it continued to retain the favor of scientists for the space of a century. Even now it is worthy to engage our attention, for in the Laplacian theory we have the Nebular Hypothesis in its most picturesque form.

Foundation of His Theory. According to Laplace's conception, every planet and satellite had once existed as a ring or belt of gaseous substance enveloping a spherical central body. For a model of his imagined primeval universe, he pointed to the planet Saturn with its attendant system of satellites and rings.

Around the equator of Saturn lie those wonderful rings, three in number, situate in the same plane, like three hoops of unequal size one within another. Much nearer the planet than its ten satellites, they cover a breadth of some forty thousand miles from outermost to innermost rim. Only a hundred miles in thickness, they are yet held together in their annular form by gravitational influence. Were they

rings of gold, they could not preserve their figure more faithfully. But they are probably made of some substance much more tenuous than gold or other metal; they are for the most part clouds of vapor carrying innumerable shining particles of solid matter.

How wonderful that this belt of attenuated gases and solids should be kept in place by the influence of the parent body! Among all the marvels of the heavens there is perhaps none quite so astonishing as Saturn's system of rings. We were familiar with the spectacle of a moon guided in its orbit by the attraction of a superior body. And we were prepared to find in space satellites wheeling about their greater luminaries. But it needed the magnifying aid of powerful telescopes to teach us that there could be a planet attended by a system of concentric rings. The disclosure of Saturn's rings came as a surprise. They are still an object of never-ceasing wonder, for nowhere in nature do we find their parallel.

Laplace's Inference. To the mind of Laplace the rings of Saturn were not merely a source of wonder, they were also an index of the life process through which every planet has passed. To him the system of rings seemed to have been left in the skies by the Creator as a memorial of the transmutations that have affected the planetary world. They are the sole visible remnant of similar formations occurring in the solar system at different periods of its history. According to Laplace, every planet and subsidiary body has appeared in one part of its career as a ring of vaporous matter. To understand well this assumption, we must trace with the great French author the genesis and development of the planets.

We have to imagine, then, the primeval sun extending far beyond its present boundaries, perhaps as far as Mercury's orbit, and around it a fiery atmosphere of incredible depth reaching the present path of Neptune and filling all the space between. It is in this solar atmosphere that the planets are contained in embryo. We have to picture the sun rotating slowly on its axis. With it rotates the far-spreading atmosphere clinging to the central body. Behold the original majestic movement from which have sprung the planetary courses!

Detachment of the Planets. At the poles of the sun the movement is scarcely perceptible while at the equator it reaches its maximum. Around the equator, therefore, tends to gather the solar atmosphere, which becomes wrapped about it as a huge girdle. As times goes on, the sun shrinks in size. Constant radiation and loss of heat causes it to contract. And as contraction proceeds, rotation becomes perforce more rapid.

The swifter the revolution, the greater the centrifugal tendency at the equator. There comes a time when this tendency to separate overcomes the powers of attraction and cohesion. The remoter part of the solar atmosphere becomes detached from the central body and forms into a distinct ring of nebulous matter, rotating about the sun and encircling it completely. That such a ring could have been sustained in space, we know from the actuality of the rings of Saturn.

As the sun with its clinging atmosphere continues to contract, the space is widened between the parent body and its tributary ring. Meantime the ring has been cooling by the radiation of heat and gaining

in compactness as it cools. If it is everywhere homogeneous and of uniform density it will retain indefinitely its annular form, and there will eventuate a permanent ring like those of the Saturnian system.

But there will probably be some regions denser than others and gifted therefore with superior powers of attraction. About these denser portions as centres, the material of the ring will gather. The densest of all will finally attract all the others, picking them up on the way, till all the materials of the ring will have congregated to form a single spherical mass. For the natural form of fluid bodies is the spherical. The annular form has been exchanged for the globular, the first true planet has come into being and it will begin now its regular periodic journeys of revolution around the sun. Thus, according to Laplace, was generated the first offspring of the sun, the outermost of the planets, the body we now call Neptune.

Formation of Other Planets. As was born the remotest planet, so also were created the other planets in like manner. As the sun continues to contract in volume, it will after an interval cast off a second ring, and later a third and fourth, in the plane of its equator. Each ring of fiery incandescent particles will revolve about the primary orb in obedience to its original impluse. As it solidifies, some parts will become denser than the rest and one densest of all, around which latter as a centre will accumulate finally the ring's entire mass.

Thus were to be generated in time the eight major planets, each in the beginning a ring cast off from the sun, of such great circumference as completely to enclose the parent sphere. The group of asteroids,

five hundred in number, in the zone between Mars and Jupiter, had a similar origin. But the ring from which they originated instead of aggregating about one dominant centre, divided itself among many different centres, with the result of producing a group of five hundred minor planets.

Creation of the Satellites. The birth of the secondary planets or satellites, the hypothesis of Laplace explains by the same chain of reasoning. Let us suppose one of the major planets fully formed. Let our specimen be preferably one of the largest, as Jupiter, the giant of the system. At the point we intercept it just turned into a sphere, it is itself a miniature sun, voluminous in extent and of gaseous constitution. Revolving with increasing rapidity, it will by the same laws cast off a ring from its bulging equator, which will in due time condense into a small globular body, tied to its immediate parent by gravitational action.

As Jupiter shrinks in size by the certain loss of heat, another and again another ring will be formed, which will successively condense into satellites, each closer to the planet than its predecessor. Seven times has the process been repeated in the case of the giant planet. When, therefore, we now survey Jupiter through the medium of a Yerkes telescope, we discover attendant on it a group of seven satellites, revolving in the plane of its equator and each circling on an axis.

The number of satellites thus produced has varied in general according to the sizes of the planets, as was to be expected. Mercury and Venus have no such accompanying body. With the others, the range is considerable, from one for our Earth to ten for Saturn.

An Appreciation. Such in brief is the history of the universe as interpreted by Laplace. Whether veri-

table or not, it makes at least an interesting story, and one that will linger in the memory. From the prince of French astronomers, Tennyson, the prince of Victorian poets, was not loath to borrow his description of the world's beginnings:

> "This world was once a fluid haze of light,
> Till toward the centre, set the starry tides
> And eddied into suns, that wheeling cast
> The planets."

OBJECTIONS TO THE LAPLACIAN THEORY.

For fifty years from its foundation in 1796 and its revision in 1808, the Laplacian theory of the origin of the solar system seems to have been universally accepted. During the last half century, however, it has been subjected to such severe and scorching criticism that its specific features have been virtually abandoned. In considering the attacks made upon it, one ought carefully to distinguish between the essence of the Nebular Hypothesis, which says no more than that the sun and its cortège of planets were once involved in a single huge nebula, and the particular process by which Laplace conceived the primitive nebula to have condensed into planetary globes. Objections to Laplace's annulation theory need not necessarily affect the Nebular Hypothesis itself.

First Difficulties Raised. Laplace himself was not unaware that his theory was open to criticism. Had it been otherwise, he would have called it a law or doctrine instead of offering it as a theory. The very title, Nebular Hypothesis, connotes a teaching not

yet fully verified or immune from the chance of error.

Laplace foresaw that against his theory of a ring-like nebula the objection might be raised that from such a nebula would be begotten globes rotating in a contrary direction to the common movement of revolution. For the inner parts of a given ring destined to form a planet would possess in his theory of contraction and acceleration, a higher velocity than the outer rim. When condensation occurred, therefore, this superior velocity would have determined the spinning of the planet in a direction opposite to its movement through space. The globe would have acted precisely as a ball thrown by a pitcher, twisting away from the side of greatest velocity.

Laplace thought to evade the difficulty by assuming a certain degree of consistency in the generating ring, and conceiving it to revolve as a unit solid mass. The supposition was, however, contradictory to his main hypothesis, and could not have given complete satisfaction even to its inventor.

Further Objections. As time progressed, it was almost inevitable that other flaws and even seams should be discovered in the scheme which Laplace had elaborated. In 1861, Babinet suggested the grave difficulty that, had the sun condensed from the orbit of Neptune to its present diameter, it would have gained such acceleration of velocity as now to rotate with more than ten thousand times its actual known speed. Or, conversely, the sun's present rotation-period being conserved, Neptune's period of revolution should be ten thousand times longer than observation shows to be the fact.

The difficulty has been recently examined and re-approved by Moulton of Chicago. It is outlined by

Miss Clerke in her splendid work, Modern Cosmogonies, published in 1905, and appears in the mind of the authoress an almost insuperable difficulty to the particular process of planetary evolution proposed by Laplace.

It was further objected by Kirkwood in 1869 that an attenuated mass such as Laplace had prescribed could not possibly have formed into rings, for the density of the original nebula was millions of times less than that of our atmosphere. How shall such a tenuous envelope assume definite ring-shaped forms? In 1884, the same critic urged in addition that it is the way of nature for rings to form from spheres, as meteor swarms, for example, are generated from comets, and not vice versa as Laplace's theory had postulated.

Newly-Discovered Facts. The more recent strictures on Laplace's celebrated theory are no reproach to the inventor, damaging though they may be to his hypothesis, for they arise from telescopic discoveries he could not possibly have foreseen. According to the terms of his theory, no satellite of a planet should revolve faster than its primary rotates. Now the inner of the two satellites of Mars, which were disclosed at Washington in 1877, has been found to revolve in a period over three times briefer than the planet's rotation-time. The inner ring of Saturn, too, surpasses its primary orb in speed of revolution. Both these attendant bodies behave recalcitrantly to the demands of Laplace's hypothesis.

Finally it will be remembered that one of the basic arguments for the Laplacian theory is that all the members of the solar system revolve concomitantly

in an almost common plane and in the same direction. In disobedience to this law of supposed universal prevalence are now found several objects which depart notably from the plane of the ecliptic and pursue a course contrary to the general movement. Thus the four moons of Uranus rise at an angle of 83 degrees from the ecliptic and move retrogressively. The orbit of Neptune's single moon is tilted at an angle of 35 degrees and the movement of this satellite is also retrograde. Sir Robert Ball considers this anomalous progression of the systems of Uranus and Neptune to be the most serious of the objections to the nebular theory. Not insuperable, however, for he essays to answer it and accomplishes his object with more than common skill.

The latest instance of departure from the law is the peculiar behavior of the ninth satellite of Saturn whose discovery was announced by Wm. Pickering of Harvard in 1899. In disagreement with all its sister satellites, some of them near neighbors, it revolves clockwise instead of counter-clockwise and thus disobeys the general orders issued to the members of the sun's command.

Modifications of the Theory. This accumulation of difficulties has cast such doubts upon the annular theory as to imperil perhaps fatally its chance of survival. The beautiful ring-like forms perfect and exquisite as the girdles of Saturn, from which the multitudes of planets and satellites were supposed to have descended, must with regret be put aside in future attempts to explain the world's evolution. The process of development from an original nebula to the existing solar family has followed some other

course than the simple, direct and formal method which the genius of Laplace had excogitated.

SUBSTITUTE THEORIES.

Already a quarter of a century ago and more there began to appear alternative theories, some of the nature of revisions, other involving radical departures from Laplace's attractive hypothesis. Faye of France, for example, while clinging to the thought of an expansive solar atmosphere equalling Neptune's orbit in its spread, conjectured that the smaller and hence nearer planets had aggregated first, instead of the outermost planet as the former theory demanded. Here was a reversal of the order of the planets' birth.

In 1879, George H. Darwin built up a strong argument to prove that the moon had been torn from the earth by some mighty cataclysm, forming immediately into a sphere instead of going through the tedious stages of annular existence. In 1885, he and Poincaré of France suggested that direct fission might have accomplished the separation of the primitive nebula into several distinct orbs. Stellar anaylsis now seems to indicate that half the stars have divided in two before their final condensation. But while there are many binary stars, whose origin has been the simple fission which Darwin assigns as the cause of the earth-moon system, the stars give no evidence of repeated fissions such as would have been required to surround the sun with its rich colony of planets.

Both Faye's and Darwin's theories, disparate as they are from Laplace's speculation, are yet Nebular Hypotheses, for both assume a nebula to have been

the starting-point of the evolution. Lockyer's suggestion, advanced in 1887, of a primordial aggregate of meteorites is equally a nebular hypothesis, substituting merely a meteoritic cloud for Laplace's gaseous nebula.

Most Recent Theories. Within the last dozen years speculation as to the mode and manner of the development of the solar realm has been, if possible, more rife than ever. With one exception, however, all the newer theories are but variations of the Nebular Hypothesis. Such was the compromise theory of Ligondès, adopted by Sir Robert Ball in 1902 in his fine work, The Earth's Beginning. Instead of assuming with Laplace a uniform motion in the aboriginal nebula, they allow an initial motion confused to a degree, which later must become harmonious through the action of physical laws. They thus escape the difficulties arising from the contrary movement of certain satellites.

The planetesimal hypothesis, put forth by Chamberlin of Chicago in 1905, is also professedly a Nebular Hypothesis. For the gaseous nebula of Laplace and the meteoritic one of Lockyer, he substitutes a nebula of multitudinous minute planets already revolving in their orbits and destined to aggregate into larger globes, the existent units of the solar system.

An Adverse Theory. The only flat contradiction to this almost unanimous trend of thought appears to be the novel opinion published this year (1909) by Prof. T. J. J. See of the United States Naval Station at Mare Island, California. That the planets, independent from the start, have been captured by the sun instead of being evolved from it as its offspring,

such is the bold position of this latest of cosmogonists. The verification of this theory would mean, it must be confessed, the death-knell of the Nebular Hypothesis.

For the moment, however, the suggestion appears not only startling but dissonant with the facts. Had the sun captured at random its attendant group of five hundred planets, it would seem that they ought now to be pursuing courses as vagrant and erratic as the comets, which enter the solar system from all parts of space and traverse highly elliptical orbits. This is only a tentative restriction, however, and See's hypothesis will receive from scientists the respectful attention that his previous scholastic achievements have justly merited.

Present Status of Opinion. There emerges from the above discussion the obvious conclusion that while the Nebular Hypothesis has been stripped of its distinctively Laplacian features, in its naked essence it is still favored by the vast majority of those competent to judge. "It is the nearly unanimous conviction of astronomers," says Chamberlin, "that the solar system was evolved in some way from a nebula of some form." The kernel of the hypothesis thus vouched for, the average reader will be less concerned about the precise form of the shell in which it is encased. But not even the average reader can stand unconcerned before the larger problem that yet remains, whether, namely, the Nebular Hypothesis itself has brought us back to the very first beginnings of the universe. The problem of the world's actual first origin still clamors for solution.

CHAPTER XXIV.

THE NEBULAR HYPOTHESIS AND CREATION.

We have seen that, despite the weaknesses of the Nebular Hypothesis, the mass of astronomers still cling to it in its essential postulate. In the wake of expert advocates have followed many priests interested in the science. Thus Fr. Guibert, a Sulpician, wrote in 1898: "It is a highly probable hypothesis, in favor of which weighty reasons exist." Similar endorsement was given it in the American Catholic Quarterly for October, 1899, in an article by Fr. Cortie, a Jesuit.

Lest this argument from authority be deemed insufficient, it may be opportune to resurvey the known facts that lend color to the nebular theory. Evidently only a brief résumé will here be possible.

The Arguments Restated. First, there is still apparent, notwithstanding exceptional instances, a general unanimity of movement among the bodies of the solar system, particularly if only the larger members be considered. The exceptions to the general law affect masses of relatively small account, as the satellites of Uranus and Neptune, the ninth moon of Saturn, and a small minority of the asteroids. The fundamental argument of both Kant and Laplace retains even now its substantial value.

As late as 1905, Miss Clerke phrased as follows her estimate of the value of this argument: "Clearly,

the unanimity of planetary motions is no result of chance; it represents quite obviously a survival of the general swirl of an inchoate mass, occupying primitively the whole recognized sphere of solar influence. Ambiguities set in only when details come to be considered."

Secondly, present facts all testify that change is the order of nature. Nothing is at rest or in a static condition. From the sun's present enormous activity exhibited in sun spots, hydrogen flames, and the corona, we must conclude that its present phase is only temporary, and that it has in all likelihood worn quite another aspect in the distant past.

Now there exist in the heavens thousands of nebulae of unequal degrees of concentration, as Herschel had affirmed. Moreover, the stars themselves betray various stages of development, the dull red manifesting greater age than the Sirian or whitish stars. If analogies avail, may not the various classes of nebulae and stars be rightly taken as a model of the vicissitudes through which our sun has passed on the way to its present perfection?

More Recent Arguments. The above basic arguments of the founders of the hypothesis are today reinforced by an array of newly-discovered phenomena. Spectrum analysis has taught us that the chemical constituents of the sun and the earth are the same as far as they can be matched. With the doubtful exception of coronium, all the thirty-six constituent elements of the sun are also localized in the earth. By no hypothesis is the identity better explained than by community of origin from a single parent body.

The internal heat of the earth, moreover, seems a relic of an earlier state in which our globe was heated

to the degree of incandescence. That the interior of the earth is more fervid than the surface, volcanos, earthquakes and geysers prove indubitably. It is hardly less certain that the earth is slowly parting with its heat, distributing it through one or another avenue to the colder regions of space. If such loss of heat has continued indefinitely through all the ages, we are forced by physical law to infer that the earth was once a vaporous mass such as the Nebular Hypothesis has fancied.

Finally, there are in the solar world formations of most peculiar character which may well be survivals of the supposed original nebula. Comets, a part of the sun's family, present the appearance of nebulous agglomerations, especially when in perihelion. The zodiacal light, too, a faint glow stretching from the sun to Venus, and the Gegenschein or Counterglow, which lies beyond the earth, are possibly the last remnants of that thin, attenuated, rarefied, yet glowing, nebulous mass from which the Hypothesis claims the solar system to have originated.

A Witness to Current Belief. The actual occurrence of nebulous substance within the borders of the solar system, is the last of a series of five phenomena cited in support of the nebular theory. The others were in reverse order, the earth's interior heat, the identical composition of earth and sun, the sun's unceasing activity indicative of change, and the harmony of planetary motions. Massed together and properly appraised, they constitute a body of evidence not to be despised.

Their effect on the current belief of scientists may be gathered from several passages in Miss Clerke's

Modern Cosmogonies, the last of her published works. From her masterly exposition of the subject we beg to cull the following quotations:

"Few, perhaps, any longer believe that planetary formation took the precise course laid down for it in Laplace's System of the World, but fewer still doubt that the entire ambit of the solar system was once occupied by an inchoate sun, and that its component bodies came into being incidentally to that sun's progressive contraction." (P. 31.)

"Laplace laid down the ground plan of a structure likely to maintain its substantial integrity, despite innumerable additions and rectifications." (P. 38.)

"That there was in the beginning a solar nebula all are agreed." (P. 82.) However, "the mystery of the foretime can never be entirely dissipated." (P. 99.)

"All the inmates of the heavens, stellar and nebular, represent quite evidently the debris of a primitive rotating spheroid. Its equator is still marked by the galactic annulus, its poles by a double canopy of white nebulae." (P. 215.)

Limitations of Science. In the theory of Cosmic Evolution thus generally accepted, we have the supreme lesson of Science respecting the origin of the universe. In tracing the growth of the solar system back to a parent nebula, in ascribing a similar genesis to the other suns scattered through space, in tentatively uniting all the stars and nebulae in an original all-embracing mass of all but illimitable extent, Science has put forth her supreme effort and has arrived at her ultimate goal.

"IN THE BEGINNING."

But the actual first origin of nature remains for Science, and must ever remain, an unfathomable mystery. Push back the beginnings as far as she may, she cannot reach the starting-point. Beyond the earliest hour to which she can turn back the hands of time, there loom the shadowy vistas of a limitless eternity.

There are problems absolutely and unattainably beyond the farthest reach of physical science, and among them is the enigma of the world's conception and birth. The step that the Nebular Hypothesis has taken brings us no nearer the solution. "There is a vital heart of things which (by mere Science) we cannot hope to reach."

Key to the Enigma. Elsewhere must we turn for the solution of the mystery. To a higher court must we appeal, invoking the decision of metaphysical philosophy. The partial, transitory phenomena of time can only be explained by a universal, unchanging Force that dwelleth in eternity. In that eternal, immutable, unwaning Power we must seek the source of all that is manifested in the material universe. Some source there must exist, and it must be adequate to all the effects spread before our senses.

A great divine energy alone can be assumed as the sufficient fount of the world's manifold activities. It is a Power of commanding intelligence, for from the materials and energies of the universe it has fashioned "an imperishable order, an impenetrable splendor." It is a living force, for out of it as one of its products has eventuated in the progress of time that ultra-

physical power which we call Life, able to bend to its own uses the purely material forces of nature.

It is finally, a conscious and personal force, for we, the last products of creation, are endowed with both consciousness and personality, assuredly not of our own contriving nor within the capacity of a blind Cosmos to bestow. In a word, underlying nature and alone adequately explaining it, we must admit a Divinity such as Christianity teaches, the First Cause of inanimate and animate creation, in the present as in the past upholding all things by the power of His word.

Reasonableness of Creation. If the acknowledgment of God is necessary, the parallel acknowledgment of His creation of the world from nothing is not unreasonable. Indeed, though Science cannot understand Creation, it is almost forced to admit it. "Science," says Clerk Maxwell, "is incompetent to reason upon the creation of matter itself out of nothing. We have reached the utmost limit of our faculties when we have admitted that because matter cannot be eternal and self-existent, it must have been created."

Whatever matter is in itself, it owes all its perfection of form and figure, of warmth and light and color, of composition and structure, and of movement in harmonious orbits, in a word, it owes all its best features, so physics informs us, to the continuous play of energy. Of all these phenomena, then, divine energy can have been the source.

As to what remains, the cold dark clod, the mist of inert lifeless atoms, what impossibility is there that this poor formless world-stuff should have been the

product of creation? All the more in the light of the newest physics, which teaches that what we call matter is only energy under a special form. If the new physics is correct, then it becomes easy even with mere reason to find the ultimate origin and first beginning of the universe, discovering it in the Divine Energy by which all other energies have been produced.

The Verdict of Faith. In the beginning God created the heavens and the earth and all the furniture thereof. Over the primeval chaos hovered the Spirit of God evolving order from confusion. "Thought instinctively pauses, "writes Miss Clerke, "before the vision of the symbolical brooding dove." And over all still reigns the same governing Providence, whose power is sufficient to sustain the harmonies of the solar system, the corporeal life of plants and animals, and the spiritual life of man.

It is the verdict of reason, strengthened by the confident judgment of faith. It breeds no conflict or clash with anything that Science offers, for between the Nebular Hypothesis and the dogma of Creation there is and can be no contradiction.

CHAPTER XXV.

SUMMARY AND CONCLUSION.

Now that we have reached the end of our journey, it may profit us to sum up its results by resurveying briefly the territory we have traversed. What was the purpose that led us on? What did we find to be the character of our path?

Fulfilment of a Purpose. In the series of studies just terminated our avowed purpose has been two-fold, to acquaint the reader with the most salient teachings of astronomy, and to prove that there exists a perfect harmony between this science and our holy religion. Our aim was partly informational and partly apologetic, to supply a certain amount of useful instruction and to defend the Church from the charge of hostility to science. Apologetics necessarily involves a measure of controversy. But the element of controversy has been reduced to the unavoidable minimum, and effort has been made to exclude entirely the controversial tone and spirit. Our sole quest has been for truth, the Holy Grail of scholastic pursuit.

In pursuance of our double purpose we have divided the work into two main parts, overlapping, however, at times, and never rigidly exclusive. About one-half the chapters deal with purely astronomical doctrine, the other half with historical apologetics. The two parts, about equal in length,

are to be appraised as of equal importance. The first or scientific section appeals to all who are interested in the "natura rerum," the nature of things, and what educated person is not? The second or historical section addresses its appeal to all who find attraction in the intellectual triumphs of the past.

Systematic Astronomy. The particular topics chosen from systematic astronomy, though few numerically and of simple character, have been selected advisedly. If in dealing with the earth, its shape and twofold movement, our treatment has appeared to some too elementary, we must protest that we have met many college graduates ignorant of the arguments for these rudimentary astronomical truths. We have therefore spread out at length the proofs of the earth's rotundity, rotation and revolution in language so simple that "he who runs may read."

The superior magnitude of the sun has been established by reasoning that even the non-mathematical student could grasp. The sun's physical nature has been described, and its unfitness for habitation put beyond doubt.

In the planetary system with its marvelous order and regularity was found what seems to us an ever-cogent argument for the existence of an intelligent God. In view of current interest in the question of the habitability of the planets, especially of Mars, we have treated this problem at considerable length. The result of our inquiry was the probable conclusion that the planets are not inhabited, and that the earth, though not the physical, is still to be esteemed the moral centre of the universe.

From the planets we passed in thought to the fixed stars, in our summary taking guidance from the volume issued in 1902 by Newcomb, the late lamented chieftain of American astronomers. Finally, the concluding chapters were devoted to a consideration of that vastest and sublimest of all astronomical theories, the Nebular Hypothesis.

The complete list, earth, sun, planets, stars, and nebular theory, is not exhaustive, but it covers in some manner the principal subjects studied in systematic astronomy.

Historical Astronomy. The second set of chapters, the historical, has invaded territory seldom explored in current manuals. Almost any good textbook of the science will be found to supply biographies of the world's master-astronomers. Hipparchus and Ptolemy of the ancient time, Copernicus, Kepler and Galileo of the Renaissance, and Newton, Herschel and Laplace of the modern period, are adequately treated in a multitude of books.

But seldom has the history been written from the Catholic point of view. The relations between the Bible and astronomy have only recently been studied in a scientific manner. In a Catholic history of the science the results of these interesting biblical researches should hold the first place. But the Bible represents only the start of the history. The way must be followed into the patristic period, the first seven centuries of the Christian era. That the Fathers of the Church were not unfriendly to astronomical science, is the important lesson this period has taught.

The Middle Ages, hitherto summarily put aside as unworthy of consideration, we have sought to

liberate from the darkness in which modern neglect had enshrouded them. Entering the Modern Period, we have come upon two changes of vital interest in the history of the science, both accomplished by members of the Church, the overthrow of the Ptolemaic theory by Copernicus, a Catholic ecclesiastic, and the reform of the calendar by Pope Gregory XIII.

To the famous Galileo case we have devoted many pages, applying the results of the best modern criticism to this delicate incident of judicial history. Finally, from the large phalanx of astronomers who have succeeded Galileo, we have brought into relief some noted scholars of the Catholic faith, Cassini, Piazzi, Secchi, Denza and Clerke, with one exception names too little known. Catholics should be made aware that these names deserve to be ranked just after the immortals of astronomical history.

The Ultimate Lesson. However treated, systematically or historically, the science of the heavens is barren of its best fruit unless it issues in a fuller, deeper faith in the existence and surpassing attributes of God. On the one side, the unfailing order of nature demands an intelligent Providence for its present explanation. On the other, the processes of nature traced back into the past conduct us finally to a divine Creator, Who has existed from the beginning and is Himself uncreated. That the nature of the Deity is mysterious and incomprehensible, science and faith agree. Both admit that the Supreme Being "dwelleth in light inaccessible." Nevertheless, through His visible productions we are able to catch some mirror-like

glimpse of His perfections. The invisible things of God, His eternal power and divinity, are known from the visible things which He has made.—Rom. i, 20.

With the pantheistic doctrine that God is an Over-Soul indistinguishable from the universe, we find, even in science, no reason for sympathy. True it is that in God "we live and move and have our being," as an inspired writer has said. True, He pervades the whole universe by His power and presence. But the Godhead is a Being apart, possessing attributes that distinguish Him definitively from the works of His creation. In the world as such there is no sign of the possession of consciousness or personality. It goes on its way blindly, like a machine directed by some superior hand. The order and marvels manifest in all its separate kingdoms connote a Superior Independent Being, intelligent and personal, omnipotent and eternal.

With the psalmist we still aver, "The heavens declare the glory of God, and the firmament announceth the work of His hands." And with Christ our Lord we still proclaim as the first commandment of man's religious life, both now and in the future, "Thou shalt love the Lord thy God with thy whole heart, with thy whole soul, with all thy mind and all thy strength."

APPENDIX.

I. TABLE OF APPROXIMATE MEASUREMENTS.

Sun. Diameter, apparent, $\frac{1}{2}°$; actual, 865,000 miles.
Volume compared with earth's, 1,300,000.
Mass compared with earth's, 331,000.

Moon. Diameter, apparent, $\frac{1}{2}°$; actual, 2,160 miles.
Average distance from earth, 239,000 miles.
Period, of revolution, $27\frac{1}{3}$ days; of phases, $29\frac{1}{2}$ days.

	Diameter.		Av. Distance from Sun.		Period of Revolution.	
Mercury,	3,000	Miles	36,000,000	Miles	85	Days.
Venus,	7,700	"	67,000,000	"	225	"
Earth,	7,900	"	93,000,000	"	$365\frac{1}{4}$	"
Mars,	4,200	"	141,500,000	"	687	"
Jupiter,	86,500	"	483,000,000		12	years.
Saturn,	73,000	"	886,000,000	"	30	"
Uranus, *	32,000	"	1,800,000,000	"	84	"
Neptune, **	35,000	"	2,800,000,000	"	165	"

*Discovered by Sir Wm. Herschel in 1781.
**Discovered by Leverrier and Adams in 1846.

II. ASTRONOMICAL LAWS.

A. Kepler's Laws of Planetary Motion:

1. The orbit of each planet is an ellipse, with the sun at one focus.

2. The radius vector of the ellipse, i. e. the line from the sun to the planet, describes equal areas in equal times.

3. The square of a planet's period of revolution is proportional to the cube of its average distance from the sun.

Note.—Laws I and II were announced in 1609, Law III in 1618.

Law I corrects the error of Copernicus, who had supposed the orbits to be circles.

Law II explains that, though the planet moves with varying speed, there is uniformity in its motion, for its line of connection with the sun traverses equal spaces in equal times.

Law III informs us that a planet's revolution-time does not increase in the simple ratio of its distance, as if all moved with the same velocity; but according to the square root of the cube of the distance, for the velocity diminishes with the distance.

B. Newton's Law of Universal Gravitation: All bodies in space attract one another with a force directly proportional to the product of their masses and inversely proportional to the square of their distance.

Note.—This law, announced in 1687, is of the highest importance, for it reveals the force in nature which makes the planets move in the orbits correctly outlined by Kepler. A planet of itself would move in a straight line forever. But it is drawn into an elliptical orbit by the gravitational power of a body of superior mass. Thus the earth draws the moon from an otherwise rectilinear path into a closed curvilinear orbit about itself as a focus. The sun determines in like manner the actual orbits of the earth and of the other primary planets.

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